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TROPICAL CYCLONES AFFECTING GUAM.(U)
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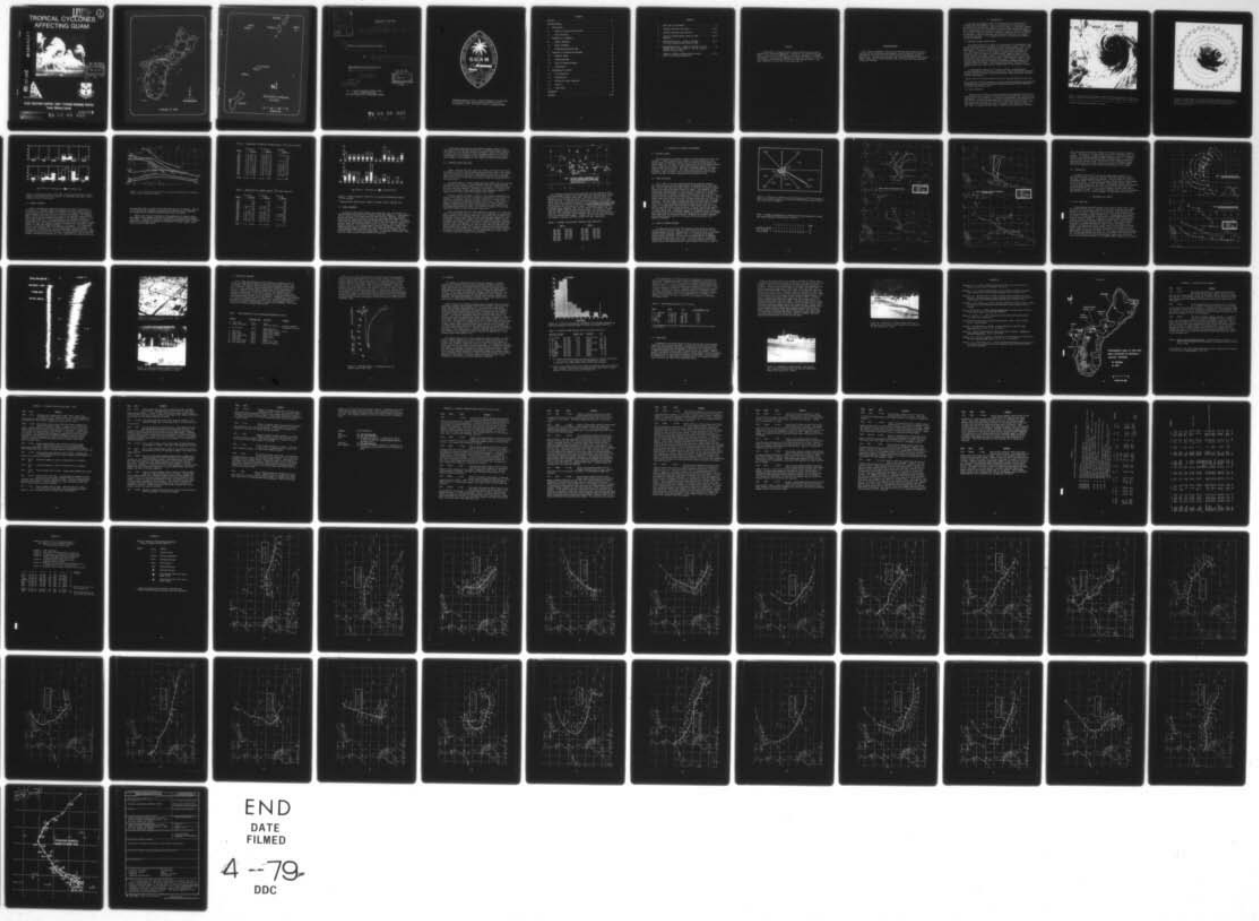

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TROPICAL CYCLONES AFFECTING GUAM

FLEET WEATHER CENTRAL/JOINT TYPHOON WARNING CENTER

Guam, Mariana Islands

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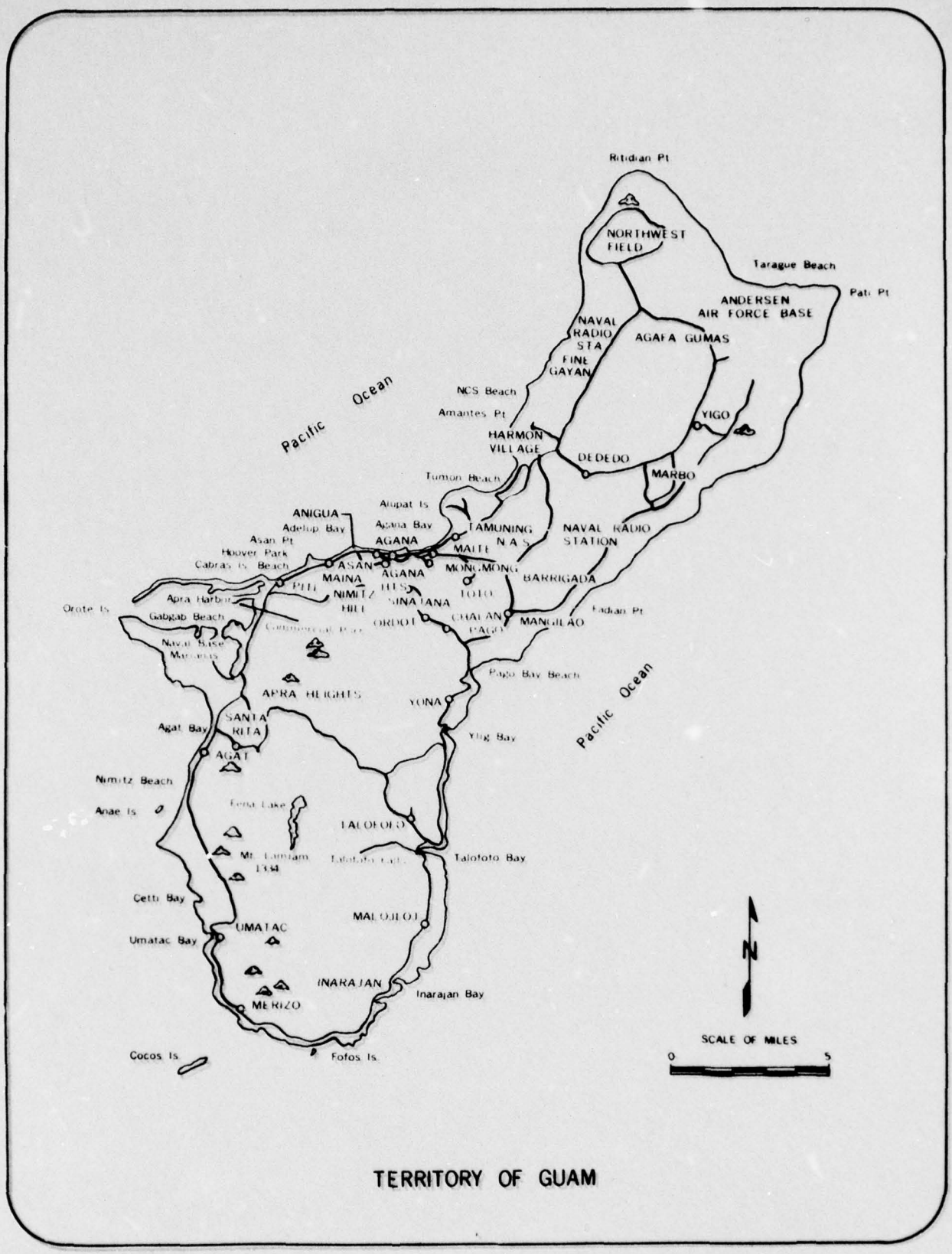

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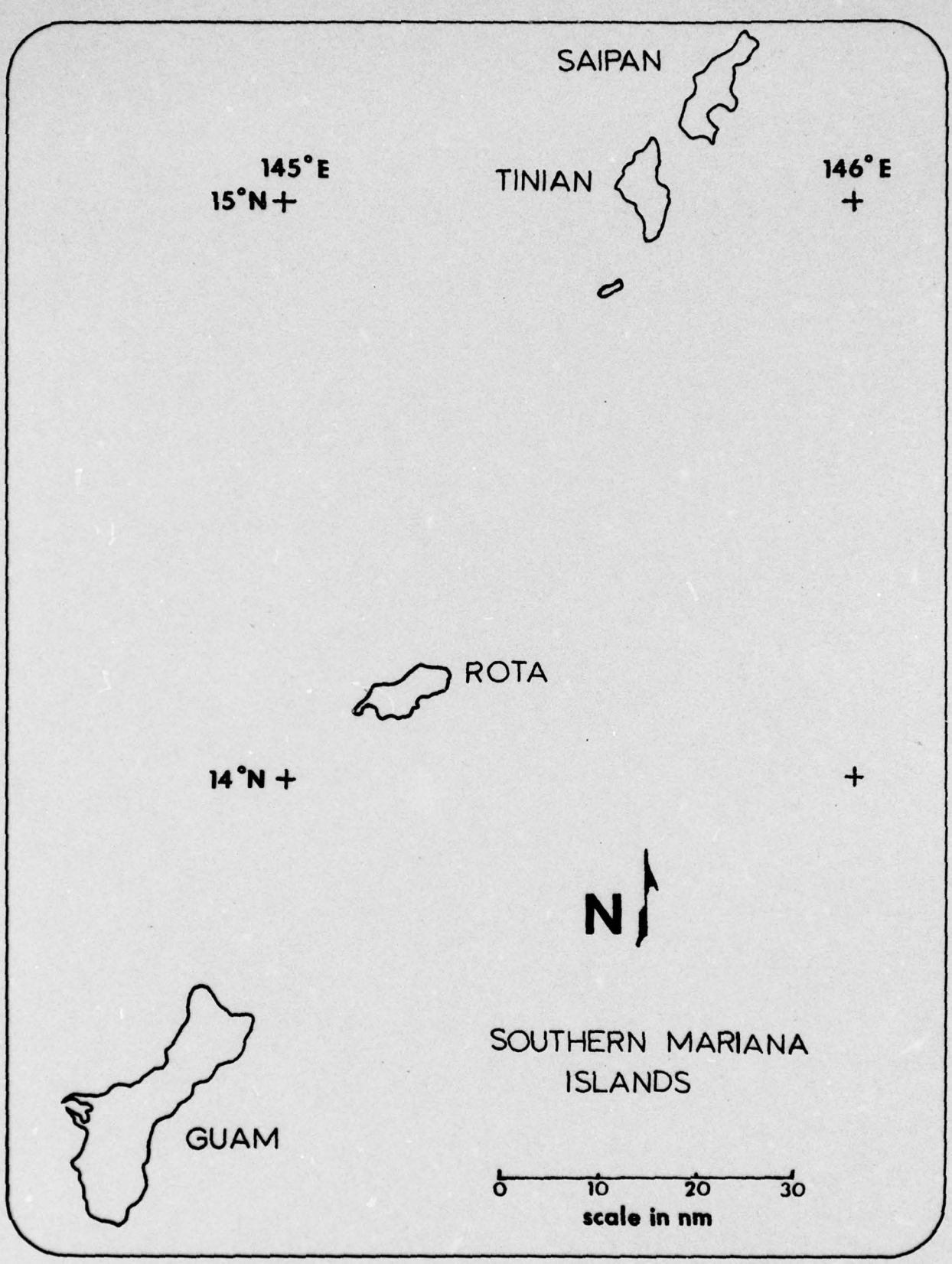
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(6) # TROPICAL CYCLONES AFFECTING GUAM.

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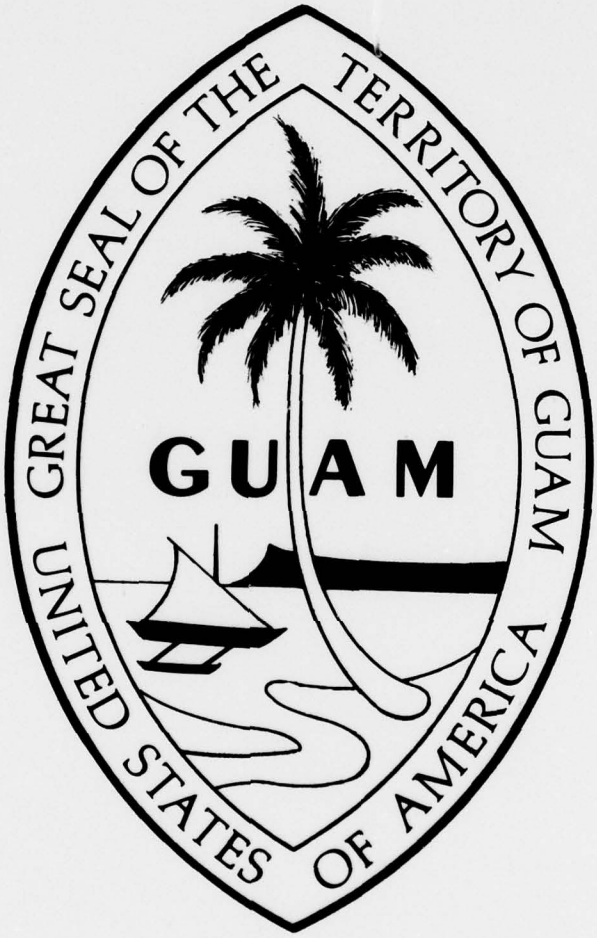

Following typhoon of 1918, a surviving palm tree at the mouth of Agana River later inspired design of Guam's official seal adopted in 1930 (fm Carano & Sanchez, History of Guam).

CONTENTS

APPENDIX

ABSTRACT

A climatology of tropical storms passing within 180 nm of Guam is presented for the period 1948-1975. A review of all typhoons affecting Guam is carried back to 1800 and some noteworthy typhoons of the 1600's are included. The survey encompasses the frequency, behavior, meteorological effects and descriptive chronicles of Guam tropical storms. The major emphasis is on the period since World War II.

ACKNOWLEDGEMENTS

The writer is indebted to the staff at the Guam Flores Memorial Public Library, and the Micronesian Area Research Center, University of Guam for assisting in the recovery of historical data on Guam typhoons prior to World War II. Special thanks are also due to Mrs. Ann Phillips, SSGT Maurice Wymore, USAF, and AG2 Terry Mickelson, USN, who helped with the manuscript typing and drafting.

1. INTRODUCTION

Guam, the southernmost island of the Mariana group, lies within the breeding ground for typhoons. Due to its position in the typhoon belt, the island is threatened year round with the passage of a developing typhoon, and on occasion one of full strength. Because of their destructive potential, these storms are of concern to military as well as civilian communities on the island. This technical note presents a composite of data concerning the behavior, frequency, extremes, and individual chronicles of tropical storms affecting Guam. It is intended to serve as a reference for general information purposes.

1.1 TROPICAL CYCLONE CLASSIFICATION

The typhoon belongs to a family of circulations in the atmosphere known as tropical cyclones which originate over the tropical oceans. One of their unique characteristics, as opposed to cyclones of the mid-latitudes, is the development of a narrow band of maximum winds encircling a relative calm eye. This characteristic of the typhoon, coupled with spiral bands of torrential rains, is capable of producing major damage in terms of wind, floods, and sea inundation. Figure 1 is a broad scale satellite view of a typhoon depicting the markedly clear weather surrounding the storm's cloud mass and coil like cloud banding about the center. Figure 2 shows a close-up radar scope presentation revealing the spiraling rainbands beneath the typhoon's high cloud canopy. The ring-like structure of the cloud wall encompassing the eye bears the most intense winds of the typhoon's circulation.

To distinguish intensities of tropical cyclones, internationally accepted definitions will be used in this study. These definitions categorize tropical cyclones in terms of sustained wind (one minute average at ten meter elevation over water):

Typhoon ($\geq$ *64 kt*), *Tropical Storm* (*34-63 kt*), *Tropical Depression* ($<$ *34 kt*)

Where required, intensity estimates of storm tracks passing near Guam have been reevaluated based on a central pressure/maximum wind relationship developed by Atkinson and Holliday, 1975.

1.2 DATA DISCUSSION

Adequate data on tropical cyclone frequency in the Western North Pacific, particularly in the vicinity of the Marianas and Philippine Sea, were generally lacking until the availability of aircraft reconnaissance surveillance in the late 1940's. Aircraft reconnaissance was introduced in the West Pacific in 1945 but was not conducted on a full-scale, year-round basis till 1948. Thus, the tropical cyclone frequency survey is limited to the period commencing with 1948. No attempt has been made to consider those cyclones of less than

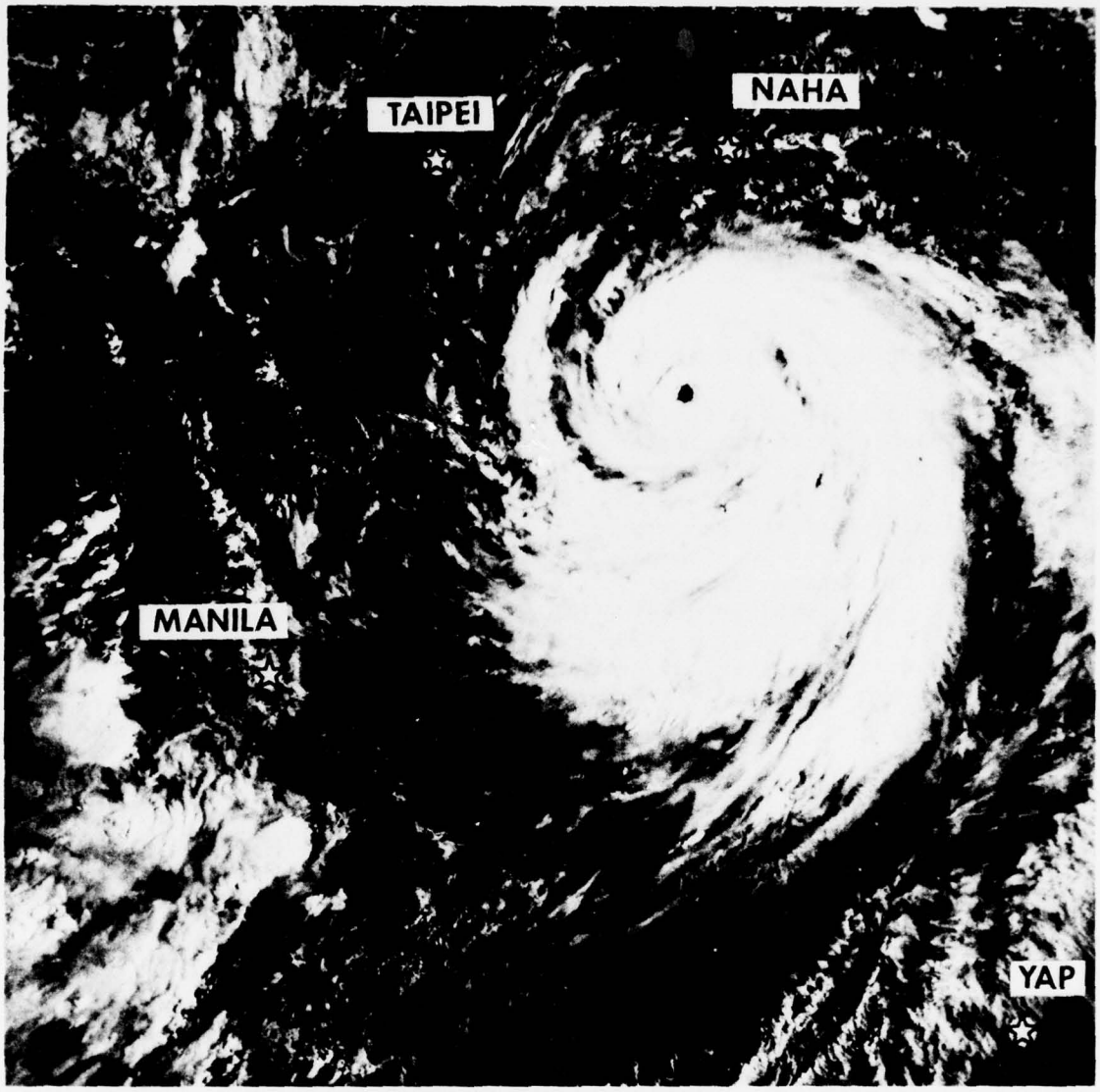

Figure 1 - Satellite view of Typhoon Betty 420 nm east-southeast of Taipei, Taiwan, 14 August 1972 (2347 GMT). (U. S. Air Force Weather Service DMSP data*)

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* Defense Meteorological Satellite Program

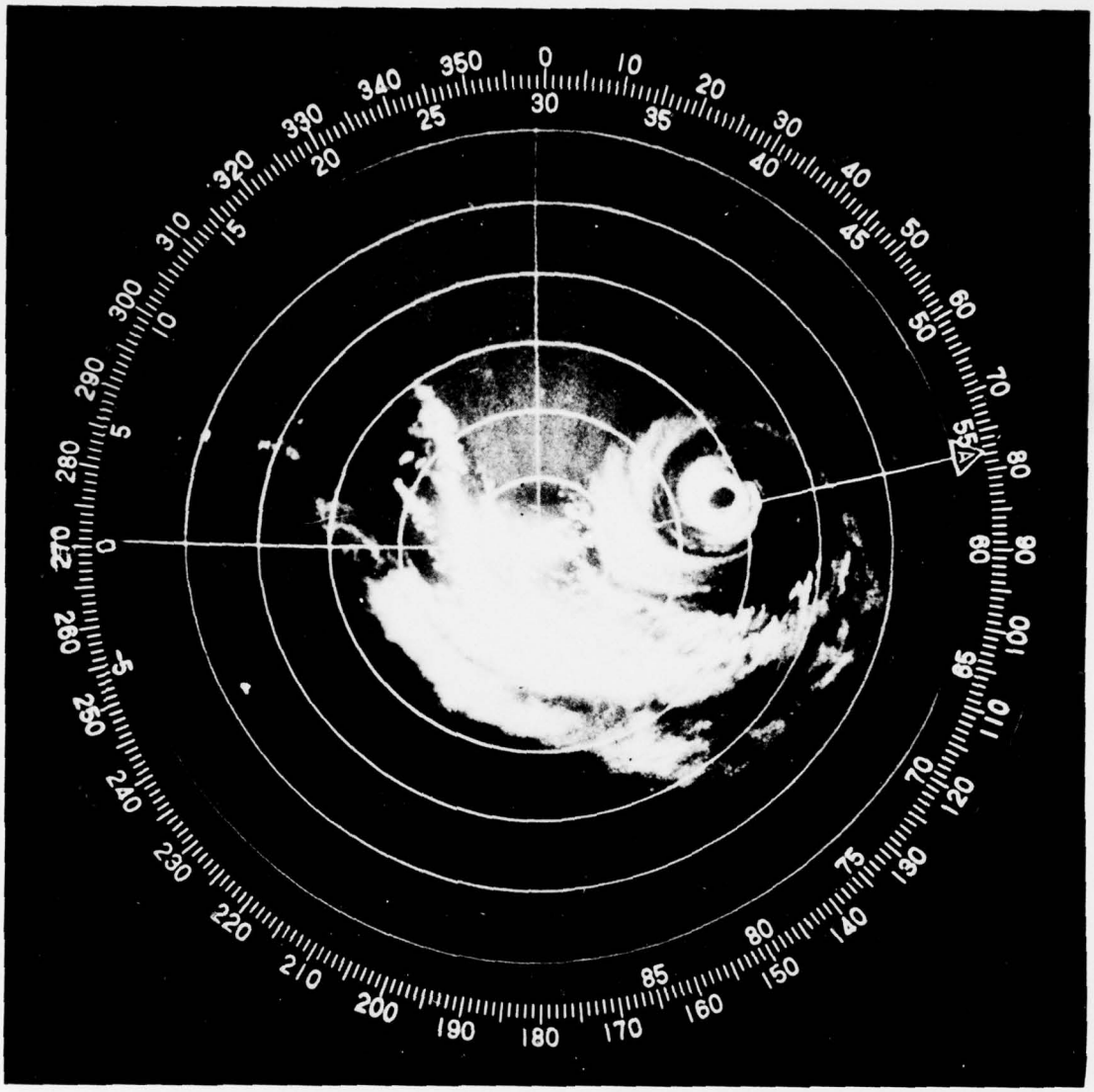


Figure 2 - Typhoon Billie as observed from the Ishigaki Jima radar on 16 July 1973 (0600 GMT) as the typhoon passed through the Ryukyu Islands. Billie's eye is located 80 nm east of the station. Courtesy Japan Meteorological Agency.

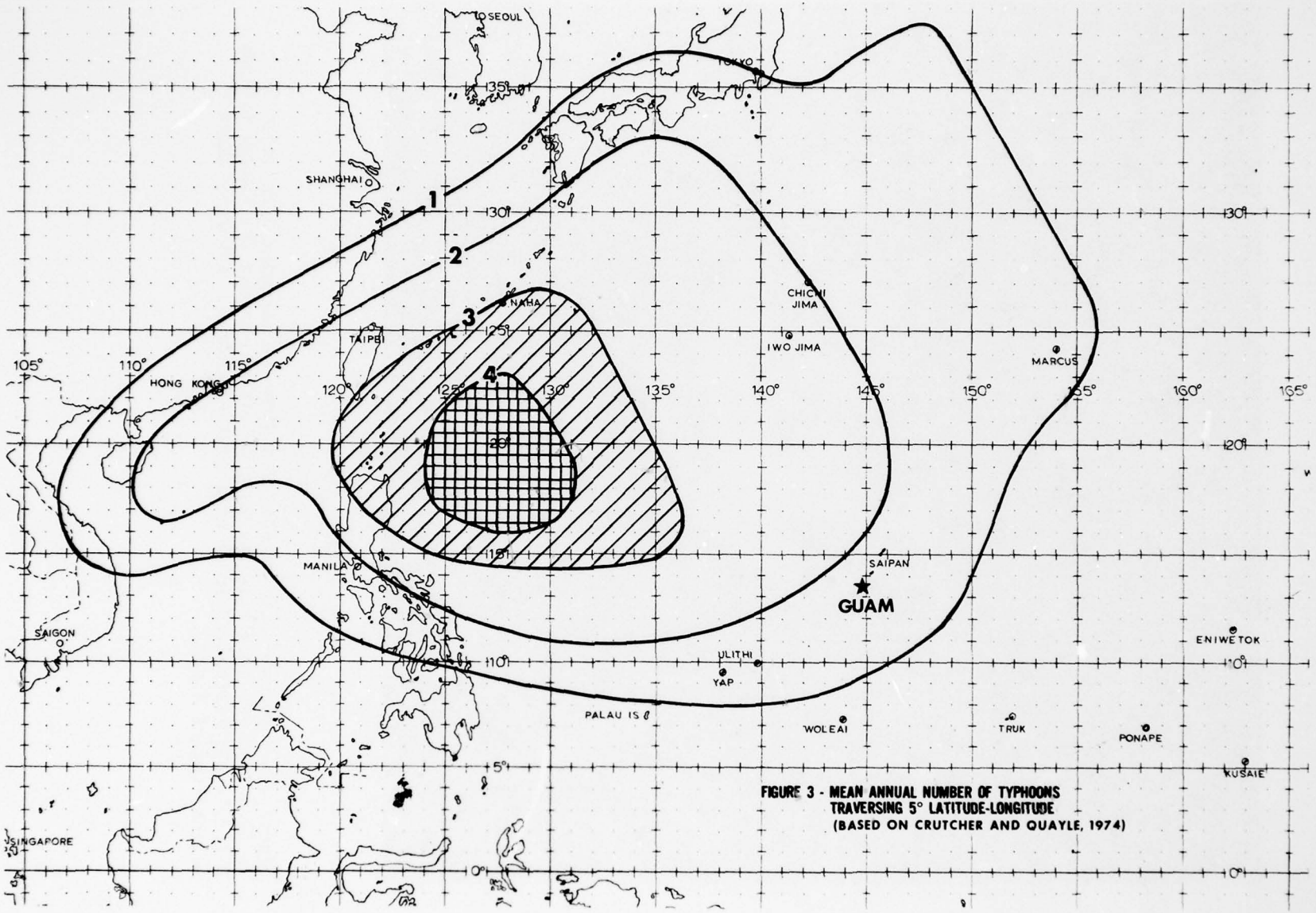


FIGURE 3 - MEAN ANNUAL NUMBER OF TYPHOONS TRAVERSING 5° LATITUDE-LONGITUDE (BASED ON CRUTCHER AND QUAYLE, 1974)

tropical storm intensity (less than 34 kts), since sufficient data on early stages of storm tracks were not available prior to routine satellite observations in 1966. The geographical area under consideration is restricted to within 180 nm of Guam since, generally speaking, the center of a tropical storm must pass within this distance to significantly affect the island with high wind, heavy rainfall, and seas. There were exceptions, however, and these are mentioned where necessary. An effort was made to survey all cases of typhoons significantly affecting Guam since 1800 to construct a long term picture of frequency and severity. In most cases these are limited to those typhoons which passed within 60 nm of Guam. All typhoons affecting Guam have been listed in the Appendix with some narrative account. For the period since 1946 tropical storms have been added in the narrative summary, and a separate listing including specific meteorological data for this period is also included.

2. FREQUENCY OF OCCURRENCE

Guam, the southernmost island of the Mariana group, lies within the breeding ground for typhoons, but is located southeast of the main zone of activity (Figure 3). On the average, at least 19 typhoons occur annually across the western North Pacific and South China Sea. Of these, several, in various stages of development, threaten Guam each year. During a 28 year record (1948-1975) 70 typhoons have developed or tracked within 180 nm of Guam with at least tropical storm strength. This is an average 2.5 storms per year or 14% of the mean annual count for the western North Pacific. Table 1 shows that only 26 (35%) were of typhoon strength at their closest point of approach to the island. This suggests a greater likelihood of a developing typhoon threatening Guam rather than one of full strength (64 kt or greater).

TABLE 1 - RELATIVE INTENSITY OF TROPICAL STORMS AT THEIR CLOSEST POINTS OF APPROACH TO GUAM (≤ 180 NAUTICAL MILES) 1948-1975*

MAXIMUM WINDS (KTS)**	CASES
35-40	25 (34%)
45-60	23 (31%)
≥ 64	26 (35%)

* - Four tropical storms not eventually developing to typhoons have been included.

** - Sustained one minute wind near center.

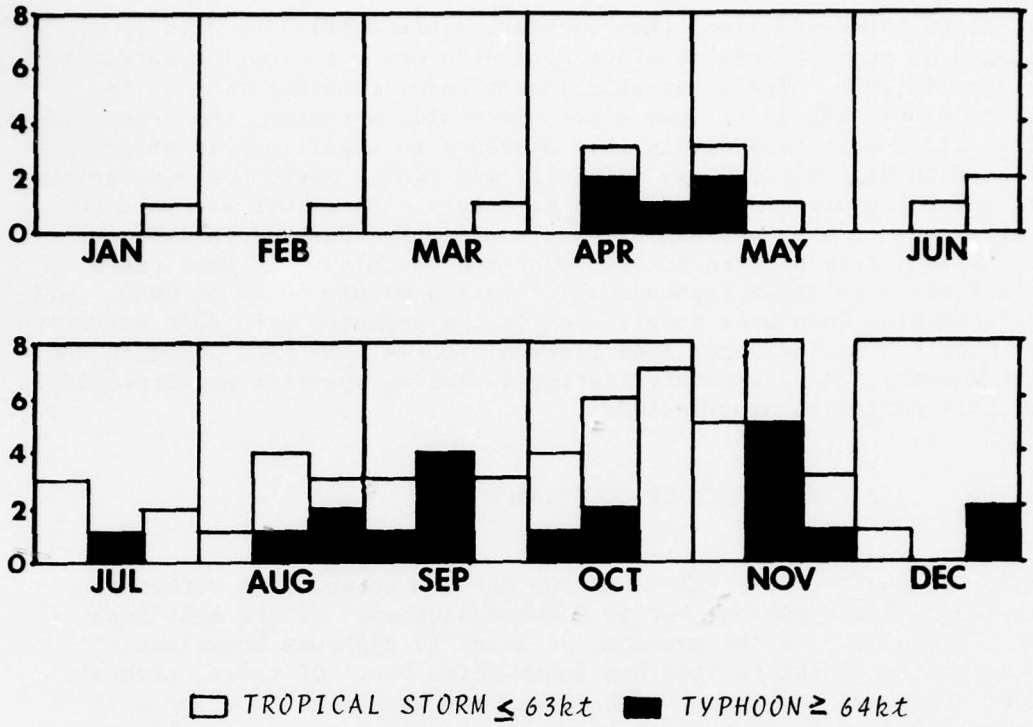


Figure 4 - Monthly occurrence (1948-1975) of Tropical Storm/Typhoon passage within 180 nm of Guam by 10 day interval (31 day months have last 11 days included in last 10 day period)

2.1 MONTHLY FREQUENCY

Figure 4 displays the monthly distribution of storms by intensity in the Guam area. Although storms have frequented the area during all months of the year, the majority (68%) are confined to the rainy season months of August-November, with peak activity in October and November. The commencement of Guam's main storm season is linked to the eastward migration of the summer monsoon trough towards the longitude of the Marianas, usually by the end of July (Figure 5). This trough provides the favorable environment for generation of tropical cyclones which may later grow into tropical storms. Towards the fall, the trough is displaced southward, and by December becomes absent, as trade wind easterlies dominate to the equator. The trough reappears at low latitudes (5°N) in the spring as westerlies occur along the equator (due to migration of a southern Hemispheric trough northward). This is temporary, and by late May easterlies once again dominate until the summer southwest monsoon migrates into the area. The presence of this low latitude trough in the eastern Carolines for a short period in the spring accounts for

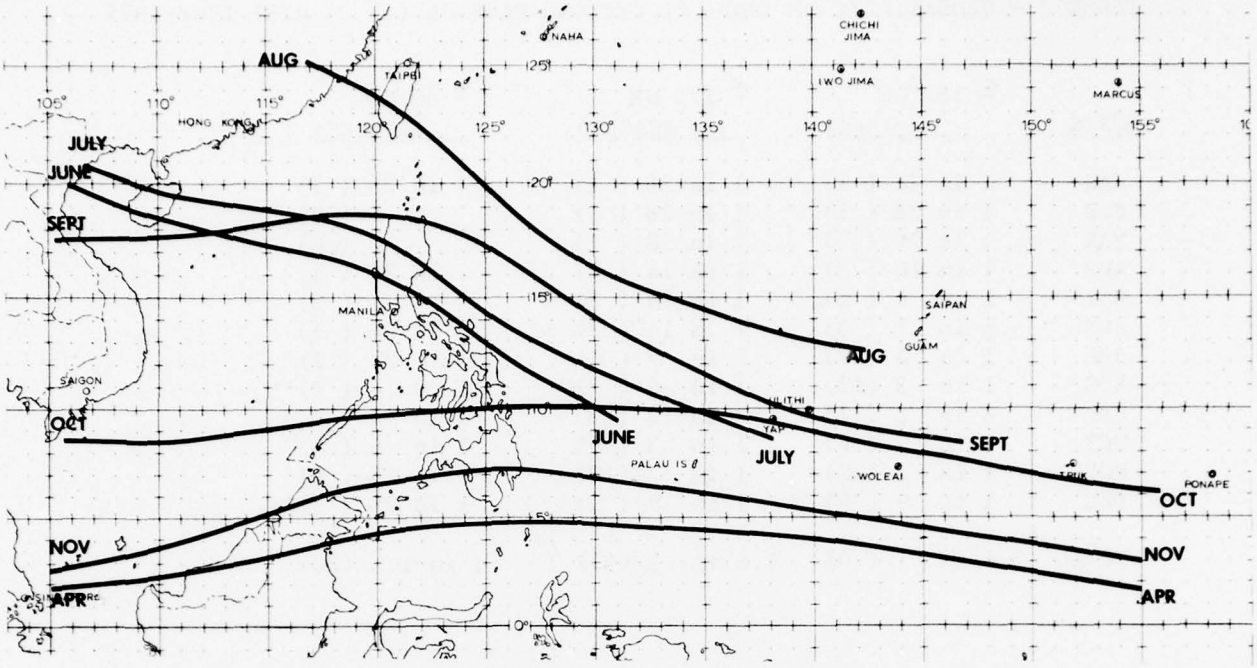


Figure 5 - Mean climotological positions of monsoon trough based on Atkinson (1970), Sadler and Harris (1970).

the secondary peak in frequency near Guam from mid-April to mid-May. Because of its low latitude position, storms have more time to mature, explaining the predominance of typhoons affecting Guam during this period.

Tables 2 and 3 give a breakdown of the probability of tropical storm and typhoon center passage within 60 nm increments of Guam based on records since 1948. It should be noted that available records prior to WW II indicate Guam has been affected by typhoons in the months of February (1864), March (1923) and June (1868, 1873).

TABLE 2 - PROBABILITY OF TROPICAL CYCLONE PASSAGE (≥ 34 KTS) 1948-1975

MONTH	≤ 180 NM (CASES)	≤ 120 NM (CASES)	≤ 60 NM (CASES)
JAN	1 in 28 (1)	1 in 28 (1)	1 in 28 (1)
FEB	1 in 28 (1)	1 in 28 (1)	(0)
MAR	1 in 28 (1)	1 in 28 (1)	(0)
APR	1 in 10 (3)	1 in 14 (2)	1 in 28 (1)
MAY	1 in 6 (5)	1 in 14 (2)	(0)
JUN	1 in 9 (3)	1 in 14 (2)	1 in 28 (1)
JUL	1 in 4 (7)	1 in 7 (4)	1 in 28 (1)
AUG	1 in 3 (11)	1 in 4 (7)	1 in 14 (2)
SEP	1 in 3 (11)	1 in 10 (3)	1 in 14 (2)
OCT	1 in 2 (16)	1 in 3 (9)	1 in 6 (5)
NOV	1 in 2 (12)	1 in 3 (10)	1 in 5 (6)
DEC	1 in 9 (5)	1 in 9 (3)	1 in 28 (1)
TOTAL	2.6 in 1 (74)	1.6 in 1 (45)	1 in 1.5 (20)

TABLE 3 - PROBABILITY OF TYPHOON PASSAGE (≥ 64 KTS) 1948-1975

MONTH	≤ 180 NM (CASES)	≤ 120 NM (CASES)	≤ 60 NM (CASES)
JAN	(0)	(0)	(0)
FEB	(0)	(0)	(0)
MAR	(0)	(0)	(0)
APR	1 in 10 (3)	1 in 14 (2)	1 in 28 (1)
MAY	1 in 7 (4)	1 in 28 (1)	(0)
JUN	(0)	(0)	(0)
JUL	1 in 28 (1)	1 in 28 (1)	(0)
AUG	1 in 14 (2)	1 in 28 (1)	1 in 28 (1)
SEP	1 in 6 (5)	1 in 14 (2)	1 in 28 (1)
OCT	1 in 7 (4)	1 in 14 (2)	(0)
NOV	1 in 6 (5)	1 in 6 (5)	1 in 7 (4)
DEC	1 in 14 (2)	1 in 14 (2)	(0)
TOTAL	1 in 1 (26)	1 in 2 (16)	1 in 4 (7)

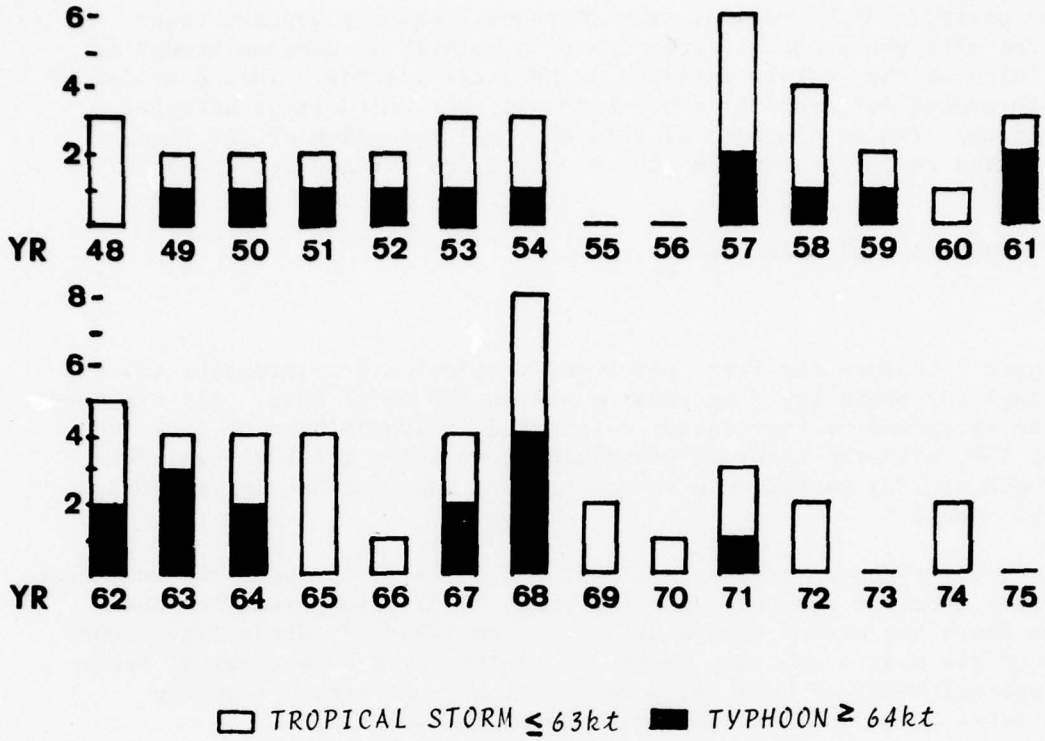


Figure 6 - Yearly Frequency (1948-1975) of Tropical Storm/Typhoon Passage ≤ 180 nm of Guam.

** Typhoon Hester passed south of Guam 31 December 1952-01 January 1953*

2.2 ANNUAL FREQUENCY

Although the mean would indicate one typhoon per year, the character of typhoon frequency has been quite irregular since 1954 (Figure 6). Approximately 40% (11 years) of the 28 year period has been devoid of typhoons. The most significant absence of activity has been the last eight years (1969-1975) in which only one typhoon (Amy 1971) has passed within 180 nm of Guam. Conversely, seven years have produced 18 typhoons or 69% of the total count for the 28 year period. These were clustered about several year groups - 1957-58, 1961-64, and 1967-early 69. It is interesting to note that during the 15 month period commencing with Gilda in November 1967 and ending with Phyllis in 1969, 12 storms traveled within 120 nm of the island. The period of highest frequency occurred between 22 October-22 November 1968. In one month, five storms - Irma, Judy, Kit, Nina, and Ora tracked within the Guam area.

The periodic high tropical storm/typhoon frequency appears to be associated with the abnormal extension of a persistent monsoon trough in the vicinity of the eastern Caroline or Marshall islands. This provided a fertile ground for tropical cyclone development which later affected the Marianas. The development of this abnormal extension of the trough may be linked to the presence of above normal sea surface temperatures.

2.3 TYPHOONS PASSING NEAR GUAM

Figure 7 depicts the first points of tropical storm intensity (34 kt or greater) for those typhoons passing within 180 nm of Guam. All typhoons (with the exception of four cases) originated as storms east of 150E and south of 15N, with the majority of points identifying the Truk-Kwajalein area (south of 11N) as the main threat area to Guam (accounting for 62% of the total cases).

The April typhoons - Georgia (1962) and Olive (1963) were the only ones to threaten from the south. [June (November 1975) also threatened Guam from the south but passed within 220 nm of the island.] Wendy (July 1963) was one of the most anomolous, beginning to intensify as a tropical storm 50 nm east northeast of Guam while moving slowly southwest, reaching typhoon force 24 hours later (80 nm south of the island).

The solid symbols in Figure 7 identify those typhoons developing sustained center winds of 100 kts or greater at the time of closest point of approach. In addition, gusts of at least 120-130 kt or nearly twice that of minimum typhoon strength (Atkinson, 1974) occur. These gusts are capable of exerting a static wind loading force four times as great a minimum typhoon because pressure force increases with the square of the wind speed (Faber and Bell, 1963). Such gusts are capable of inflicting significant damage on most unreinforced structures.

Since the maximum winds of these typhoons are confined to a tight ring about the eye (usually not more than 40-50 nm in diameter), an essentially direct passage of the center is required to experience their extreme forces. Subsequent to 1946, Karen (1962) has been the only major typhoon to cross the island, although Allyn (1949), Lola (1957) and Olive (1963) could be considered near misses. Based on central pressure, the strongest typhoons at closest point of approach to Guam were: Lola 1957 (900 mb), Nancy 1961 (905 mb), Allyn 1949 (909 mb), Amy 1971 (910 mb) and Karen 1962 (912 mb). These cyclones were of the "Super typhoon" category with sustained center winds $\geq$ 130 kt (gusts $\geq$160 kt). Typhoons Allyn, Nancy and Karen continued to deepen as they moved westward into the Philippine Sea; in every case the central pressures reached less than 890 mb.

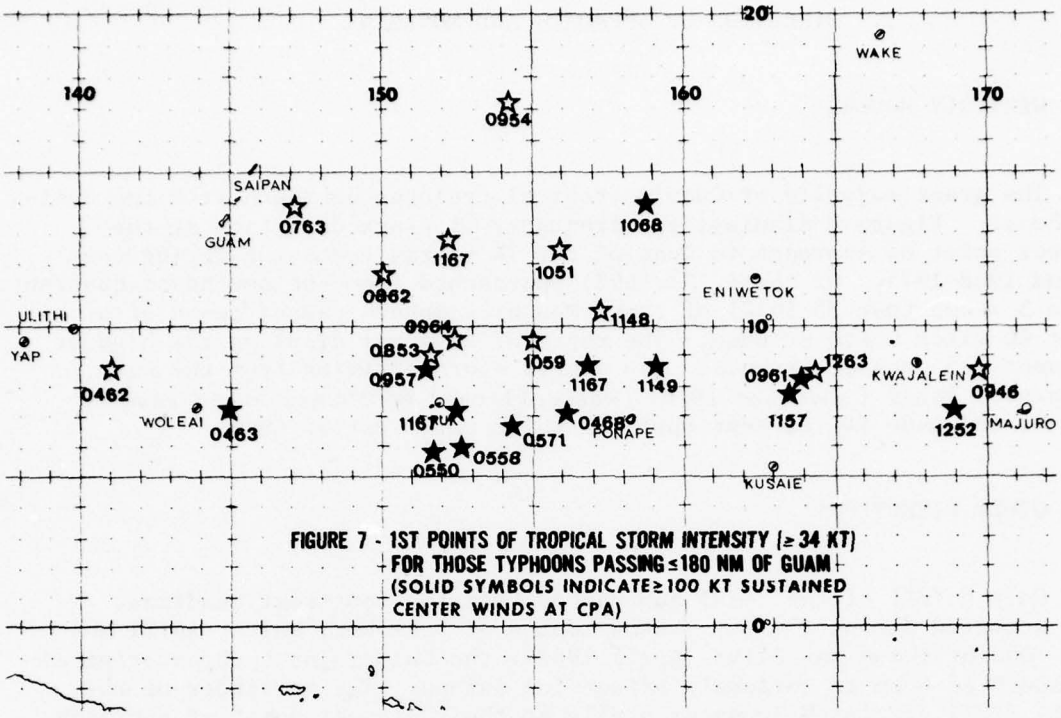


FIGURE 7 - 1ST POINTS OF TROPICAL STORM INTENSITY (≥ 34 KT) FOR THOSE TYPHOONS PASSING ≤ 180 NM OF GUAM (SOLID SYMBOLS INDICATE ≥ 100 KT SUSTAINED CENTER WINDS AT CPA)

For typhoons significantly affecting Guam (causing widespread major structural damage), Table 4 lists individual cases and provides a monthly distribution of incidences since 1800. Generally speaking, Table 4 is limited to cases in which the center passed over or just south of the island ($\leq$ 60 nm). A compilation of all storms appears in the Appendix. The 26 cases noted indicate a probability of one typhoon every seven years significantly affecting the island with a monthly maximum in November (9), and an absence of any activity in January. Evaluating relative extent of damage, Karen (November 1962) and the typhoons of November 1940, July 1918 and November 1900 were particularly severe. The typhoons of April 1807, May 1848, September 1855 and October 1891 were also notably destructive. For comparison, Karen, November 1962, was the most destructive since the November 1900 typhoon. Looking into the early years of record, the typhoon of November 1693 was probably the most catastrophic.

TABLE 4 - TYPHOONS SIGNIFICANTLY AFFECTING GUAM (1800-1975)

1800's		1900's	
APR 1807	FEB 1864	MAY 1900	AUG 1941
MAY 1847	JUN 1868	NOV 1900	SEP 1946
AUG 1848	NOV 1870	OCT 1911	NOV 1949
SEP 1855	AUG 1872	NOV 1913	NOV 1957
APR 1859	DEC 1876	JUL 1918	NOV 1962
NOV 1860	OCT 1891	MAR 1923	APR 1963
NOV 1861		NOV 1940	

3. DIRECTION OF APPROACH AND MOVEMENT

3.1 WESTERLY MOVERS

The great majority of Guam's tropical cyclones approach from the east-southeast. Figure 8 displays the frequency of track direction at the closest point of approach to Guam of the 74 storms occurring during the period 1948-1975. Of these, 51 (69%) approached from the southeast quadrant. Table 5 shows that 35 (62%) of these westerly movers passed south of a point 60 miles north of Guam. The month of November displays the highest frequency of such occurrence. The single storm arriving from the east northeast, Patsy (November 1970), was deflected southward after passing Saipan, and made its closest approach while northwest of Guam.

3.2 OTHER DIRECTIONS

Only 6 (8%) of the total approached from the southwest quadrant. Four occurred during the dry season months of December, March, April and May. One of these was Olive (April 1963), the only major typhoon originating south of Guam to seriously affect the island. The remainder of the storms (22%) displayed loops or stalls at their closest point of approach, or performed major deviations in track making it difficult to assume a uniform direction of motion. Figures 9 and 10 display the tracks of these storms with Lola (October 1963) being one of the most erratic movers. Lola's center passed over Guam while it was a tropical depression, only later to return as a tropical storm, skirting just west of the island as it tracked northward. Two other unusual storms were Violet (October 1961) and Wendy (July 1963). Both exhibited southwesterly movement near Guam only to shift to a northwesterly path once west of Guam. Nearly half (7) of the erratic cases were noted to have occurred in October with another quarter (4) occurring in July. Examination of the 16 storms passing near Guam in October shows that 11 exhibited changes of 45 degrees or more in heading while within 180 nm of the island, marking this month as having the greatest percentage (69%) of non-uniform movers. November, by contrast, displays quite steady movement with 13 of 14 storms not deviating more than 20 degrees in heading.

3.3 SPEED OF FORWARD MOVEMENT

The majority of the storms (71%) passing within 180 nm of Guam at closest point of approach range in forward speeds from 7-16 kt with the average movement 11.5 kt. Seasonal variability from the mean is noticeable with the months September-October close to the average, April-August slightly slower (9-10 kt), and late fall and winter months of November-March significantly faster (14-15 kt). Of course there is considerable variability in individual storm cases. Two of the fastest movers were typhoon Hester which passed south of Guam (December 1952) with a speed of

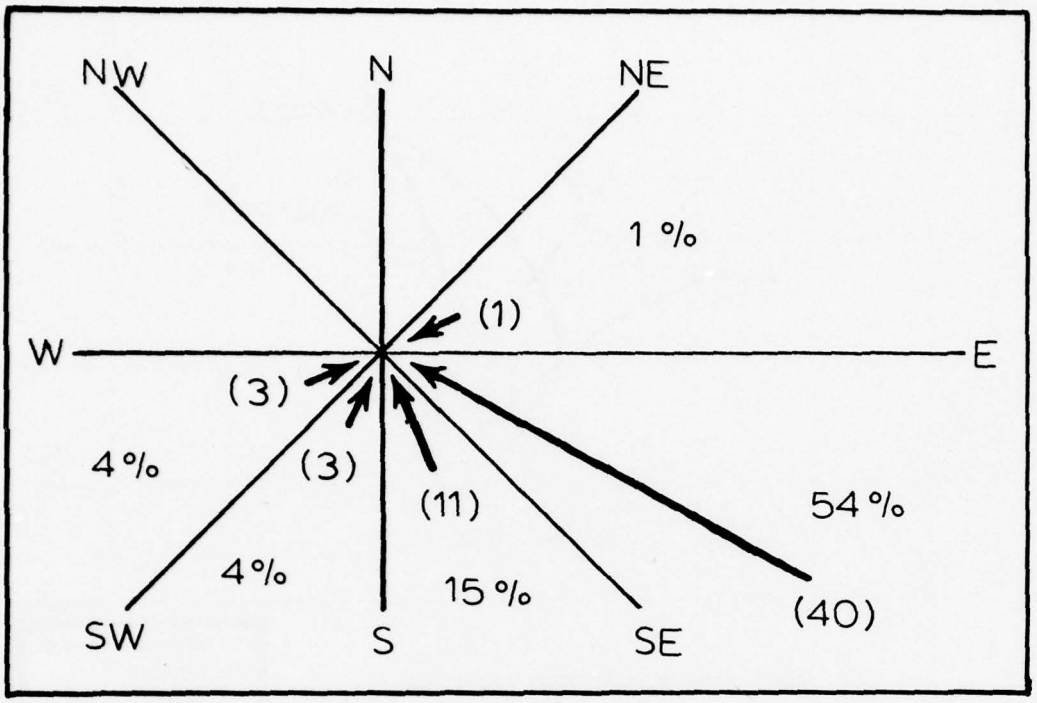


Figure 8 - Direction of Approach of Tropical Cyclones (≥ 34 kt) (length of each line represents number of occasions on which cyclones approach from each octant of the compass).

TABLE 5 - MONTHLY DISTRIBUTION OF DIRECTION OF PASSAGE (RELATIVE TO GUAM) FOR STORMS APPROACHING FROM THE EAST 1948-1975

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
> 60-180 nm NORTH	0	0	0	1	1	1	1	3	6	5	2	1	21
≤ 60 nm NORTH to 180 nm SOUTH	1	1	1	0	3	2	3	4	4	5	12	0	35

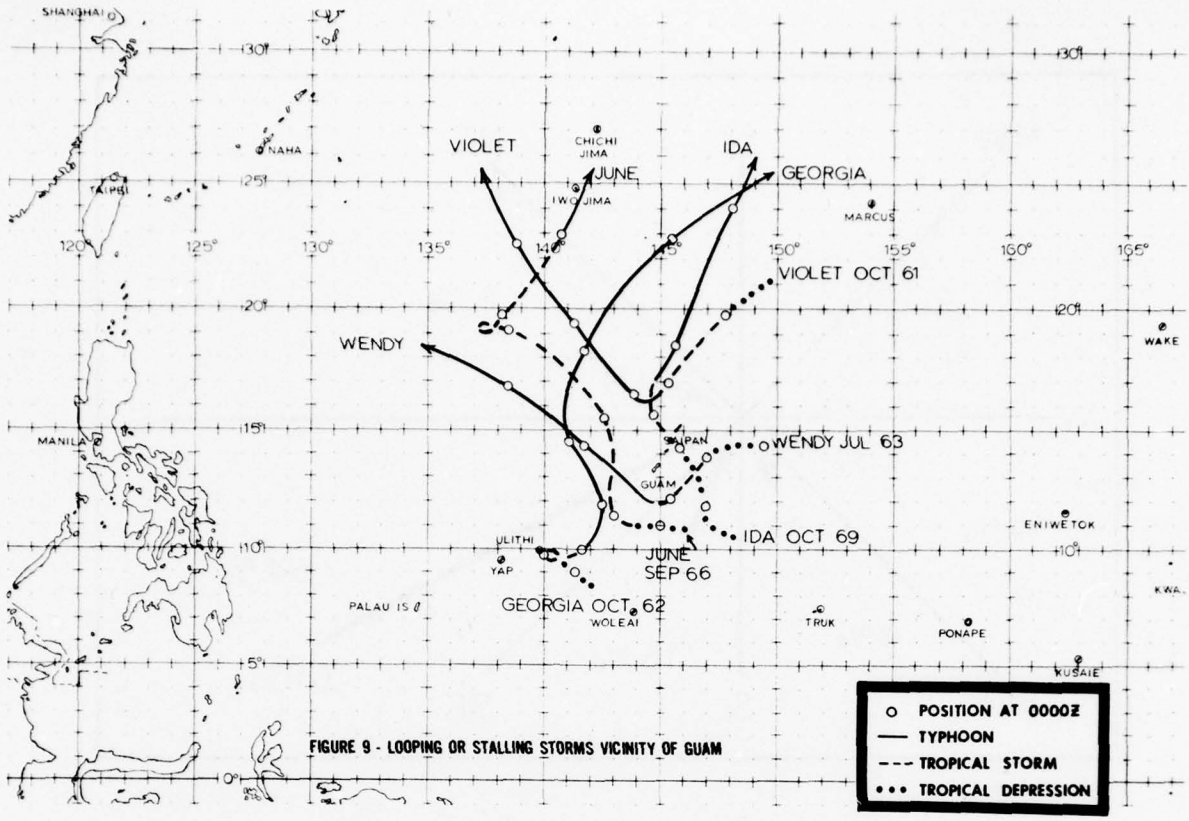
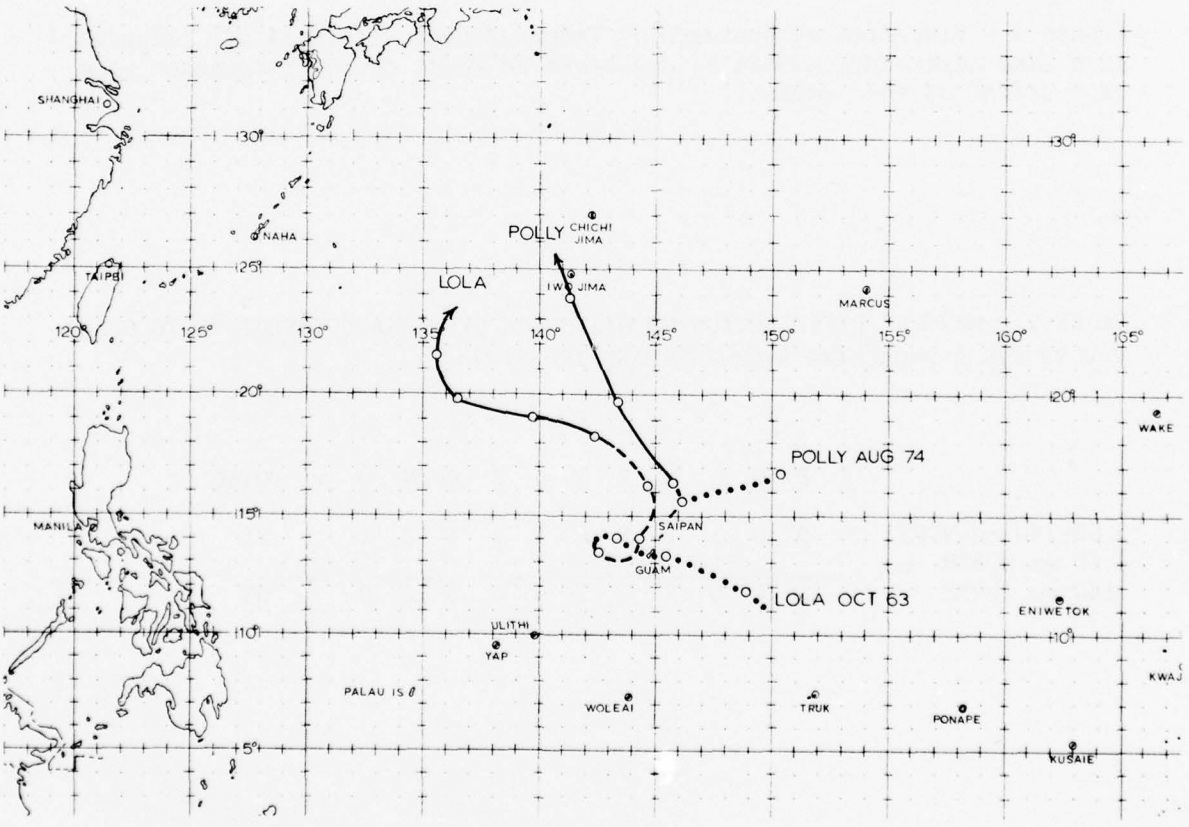


FIGURE 9 - LOOPING OR STALLING STORMS VICINITY OF GUAM



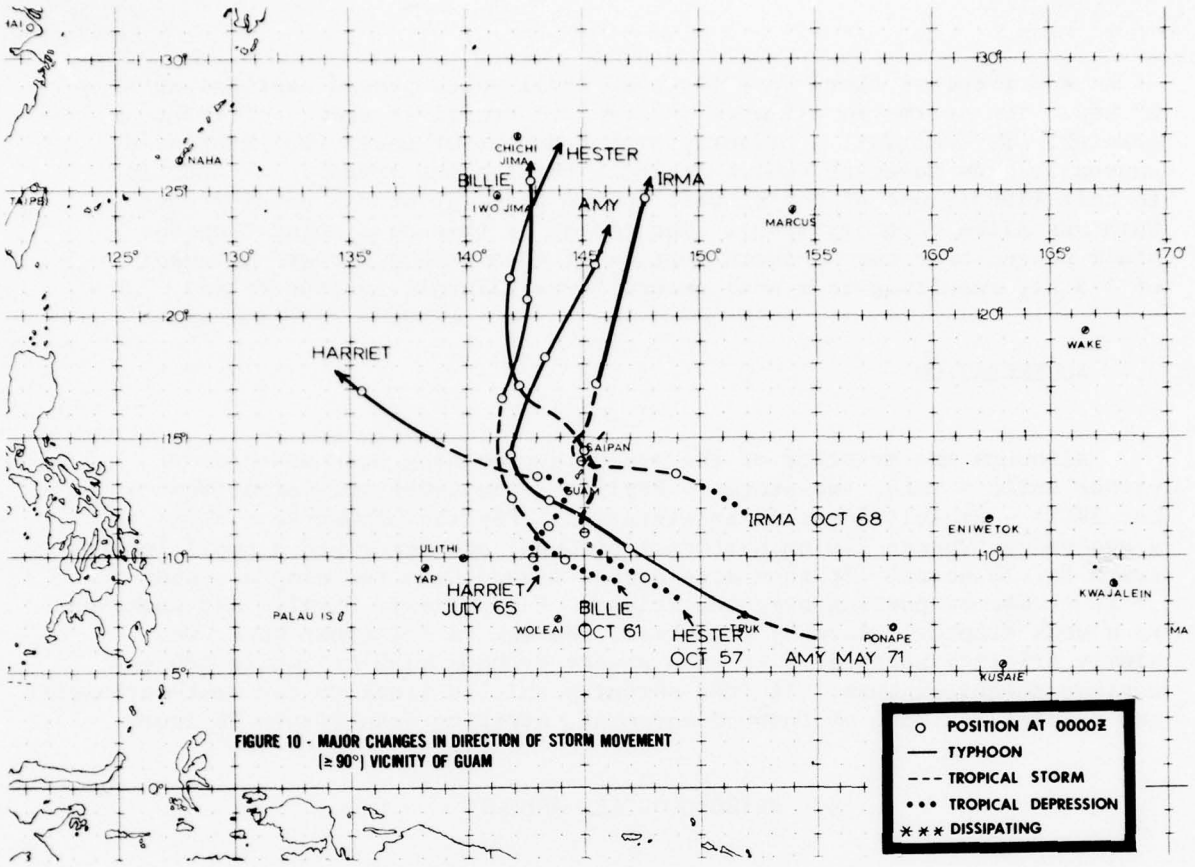
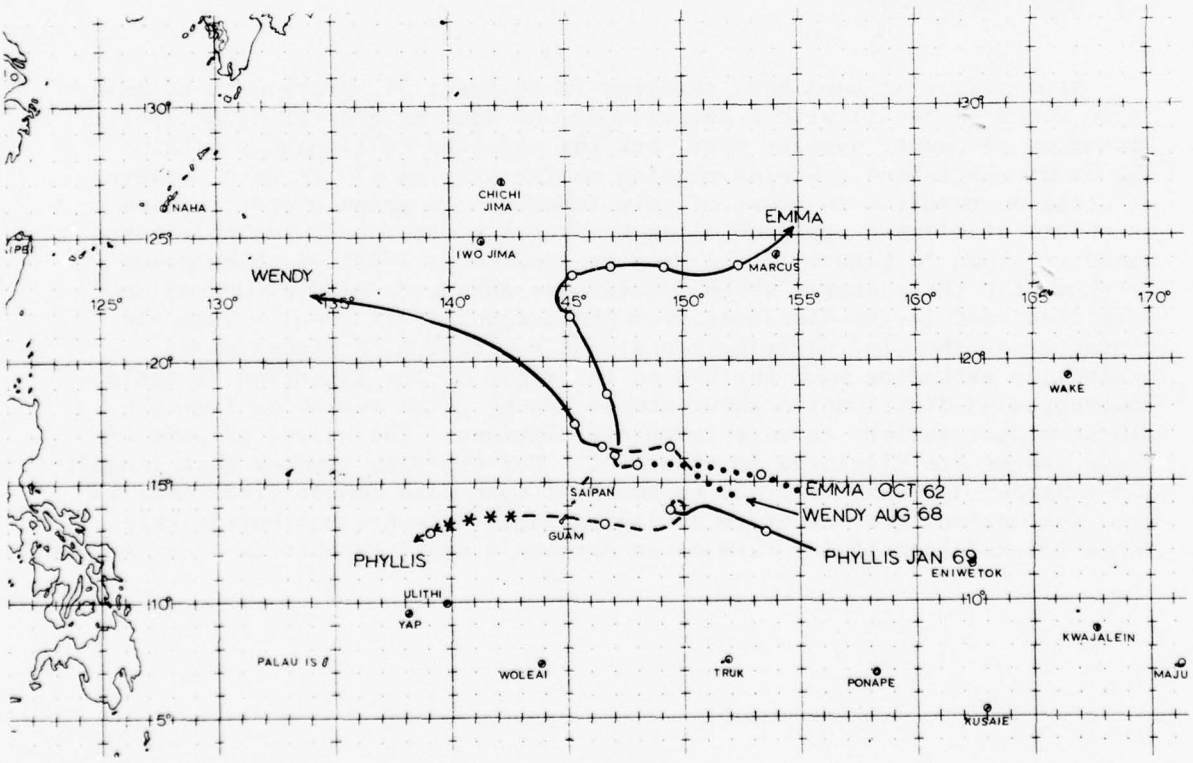


FIGURE 10 - MAJOR CHANGES IN DIRECTION OF STORM MOVEMENT (≥ 90°) VICINITY OF GUAM



22 kt and tropical storm Faye (October 1971) which passed near Saipan at 27 kts. Ten storms in all were observed to travel at speeds of 19 kt or greater. By contrast, a slightly higher number of cases (13) displayed unusually slow movement (which includes the looping cases). In addition to Lola (1963), one of the slowest moving tropical storms passing near Guam was Alice (October 1953). The center of this developing tropical storm passed over the northern portion of Guam with a forward movement of 4-5 kt, resulting in a near record 24-hr rainfall for the island.

3.4 ACCELERATION

Although the majority of the storms approaching Guam moved at a rather uniform rate, two storms - Phyllis (June 1969) and Karen (November 1962) - exhibited marked acceleration. Phyllis slowed to a stall as a weakening typhoon 270 nm northeast of Guam, and described a small looping track for 18 hours. It then accelerated toward Guam reaching a speed of 20 kt before passing over the island. Fortunately, Phyllis had weakened to a weak tropical storm by this time. Karen, on the other hand, was slowly drifting north at 5 kt as a severe typhoon (120 kt) while 480 nm east-southeast of Guam. It then abruptly shifted track to the west-northwest and tripled its rate of forward movement, striking Guam within 36 hours.

4. METEOROLOGICAL ASPECTS

4.1 GALE CONDITIONS

Storms passing Guam have resulted in at least 55 occurrences of gale force winds ($\geq$ 34 kt) with a duration of one hour or greater since 1948. Distances of center passage vary, but the majority (87%) passed within 180 nm of the island. Storms passing as far away as 450 nm have, however, on occasion resulted in gusts of gale force. A geographic distribution of points of closest approach along tracks of storms producing gale force winds is shown in Figure 11. A greater occurrence (70%) of these gales is shown for those storms which passed over and south of Guam and which were displaced larger distances from the island. This results from the character of the wind distribution around a storm, with higher winds ordinarily extending much further to the right of the direction of motion. However, wind distribution about storms can be quite variable, from the almost midget variety to very large circulations. The tracks of some of these storms are displayed in Figure 12. For example, typhoon Faye (August 1957) passed approximately 135 nm south of Guam with center winds near 100 kt. The maximum gust recorded during passage, however, was barely gale force (34 kt) identifying Faye as an extremely small typhoon in areal extent.

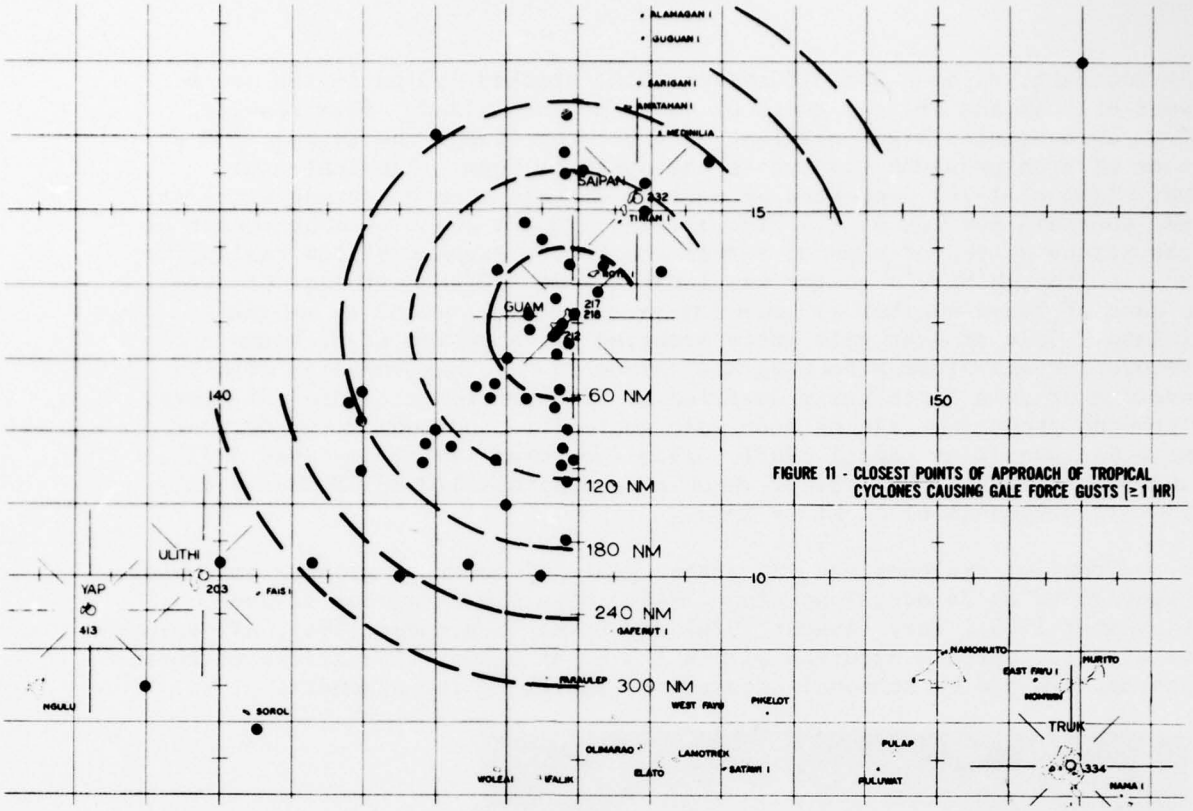


FIGURE 11 - CLOSEST POINTS OF APPROACH OF TROPICAL CYCLONES CAUSING GALE FORCE GUSTS (≥ 1 HR)

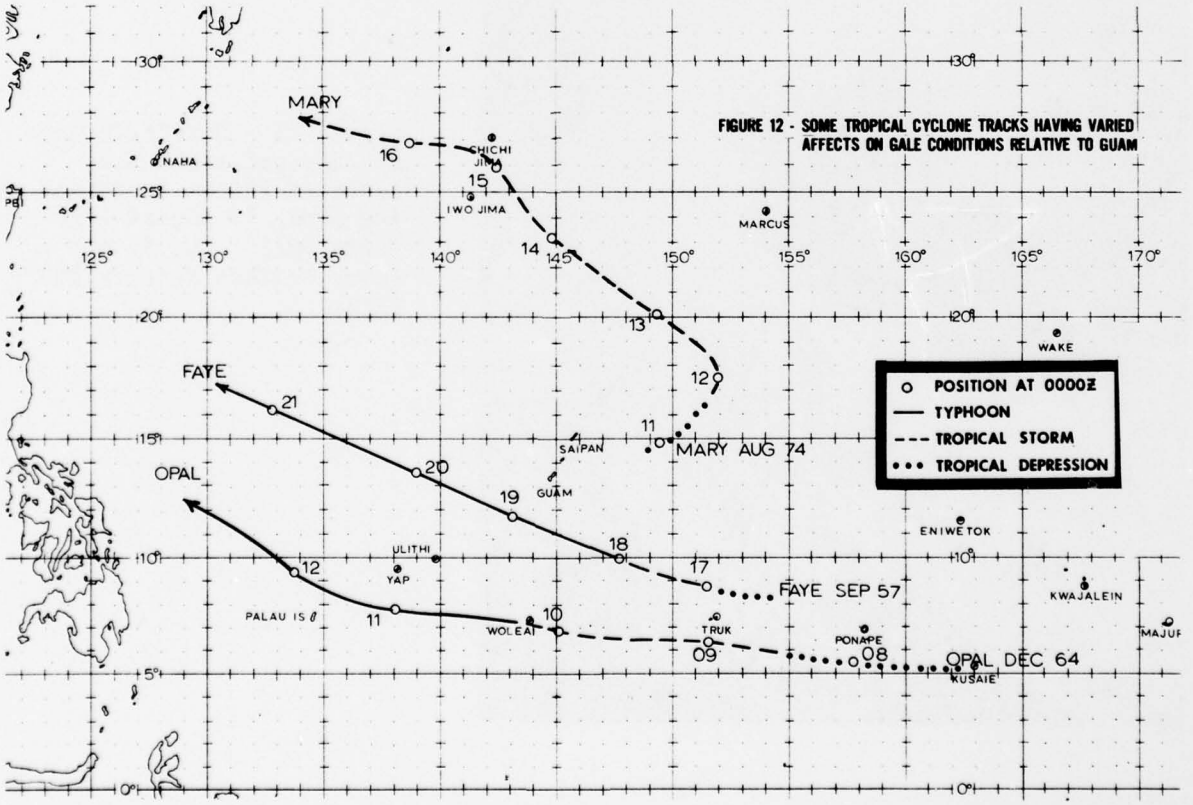


FIGURE 12 - SOME TROPICAL CYCLONE TRACKS HAVING VARIED AFFECTS ON GALE CONDITIONS RELATIVE TO GUAM

By contrast, typhoon Opal (December 1964) tracked 450 nm to the southwest of Guam and brought gusts of 43 kt to the island. This resulted from an unusually tight gradient of pressure between the typhoon and a zone of high pressure ridging to the north of Guam. Tropical storm Mary (August 1974) presented an unusual distribution of strong winds in the southern portion of its circulation, brought about by enhancement of the strong southwest monsoon across the entire expanse of the Philippine Sea. Although Mary's center was located some 450 nm northeast of Guam, a band of heavy weather (Figure 13) produced gusts to 57 kt on the island. Gale or near gale gusts occurred for a period of 67 hours - a record for any storm affecting Guam since 1945. This compares with an average of gale force gusts duration of 15 hours for the total 55 cases. Typhoons producing gale of near gale gusts for a period of two days or more include Olive (April 1963), Gilda (November 1967), Amy (May 1971), and Jean (April 1968), all of which passed within 120 nm of Guam with forward movements of 11 kt or less.

Tropical cyclones causing strong gusts of 50 kt or greater have been experienced on 24 occasions since 1946. With the exception of June (November 1975), Mary (August 1974) and Lorna (September 1954), all points of closest approach occurred within 120 nm of Agana. The tracks of these storms, grouped by seasonal occurrence, appear in the Appendix.

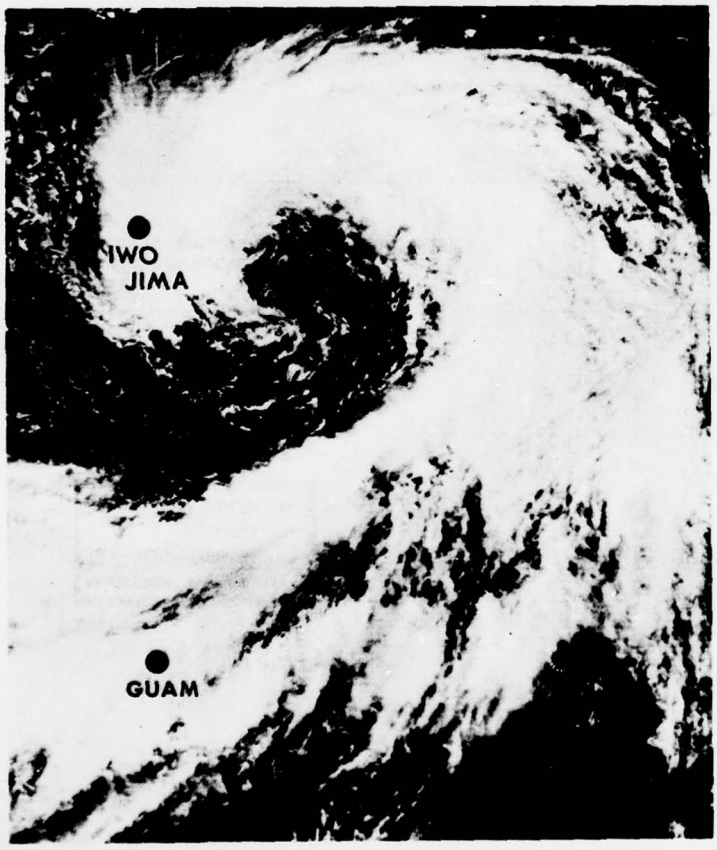


Figure 13 - Satellite view of tropical storm Mary centered 220 nm southeast of Iwo Jima, 14 August 1974 (0118 GMT). (U. S. Air Force Weather Service DMSP data)

4.2 MAXIMUM WINDS

The strongest wind gust ever recorded in a typhoon was 166 kt near the eye of Cora (September 1966), at the Japanese Meteorological Station on Miyako Jima (elev 132 ft). Wind gusts are undoubtedly higher in typhoons, but during the rare occurrence of a well developed typhoon passing near a meterological station, weather conditions are so extreme that the anemometer often fails or is blown away. Table 6 lists some of the wind extremes measured on Guam, with the casualty toll on anemometers rather evident.

TABLE 6 - SOME WIND EXTREMES MEASURED ON GUAM

	TYPHOON	PEAK GUST (KTS)	LOCATION	ELEVATION (FT)
1.	Karen (Nov 1962)	125*	Nimitz Hill (FWC)	634
2.	1923 (March)	122*	Sumay (MCAS)	25
3.	1940 (Nov)	110*	Agana (Fort Apugan)	182
4.	1941 (Aug)	108	Agana (Fort Apugan)	182
5.	Olive (Apr 1963)	87	Nimitz Hill (FWC)	634
6.	Lola (Nov 1957)	84*	Naval Air Station	255
7.	1946 (Sep)	82*	Naval Air Station	255
8.	Ora (Nov 1968)	77	Andersen AFB	644

* Anemometer Failed

With the exception of the November 1900 typhoon, Karen (1962) was the most intense typhoon to strike the island this century. With a central pressure of approximately 912 mb, the pressure-wind relationship of Atkinson and Holliday 1975 would estimate sustained (1 minute) over water winds of 130 kt, with gusts to 160 kt. Due to topographical effects wind intensity over land can be distorted, producing gusts greater than those over water. Wind gusts to 180 kt were estimated at certain locations on the island.

A notable characteristic in the Karen windspeed record is its non-steady nature (Figure 14). This gustiness - peaking, then dropping to a relative lull - is seen to vary as much as 80 kt in a matter of minutes. This pulsating and gusty nature of the wind results in uneven and intermittent pressure and wrenching effects. It is also significant that the wind causes not only a pressure on the windward side but also a suction effect on the leeward side of structures.

During Karen, this fluctuation of wind intensity resulted in extremely large pressure differences (60-70 lb/ft^2) in less than a minute during passage of the eye. Few unreinforced structures were able to withstand such blasts (Figures 15 and 16).

FIGURE 14

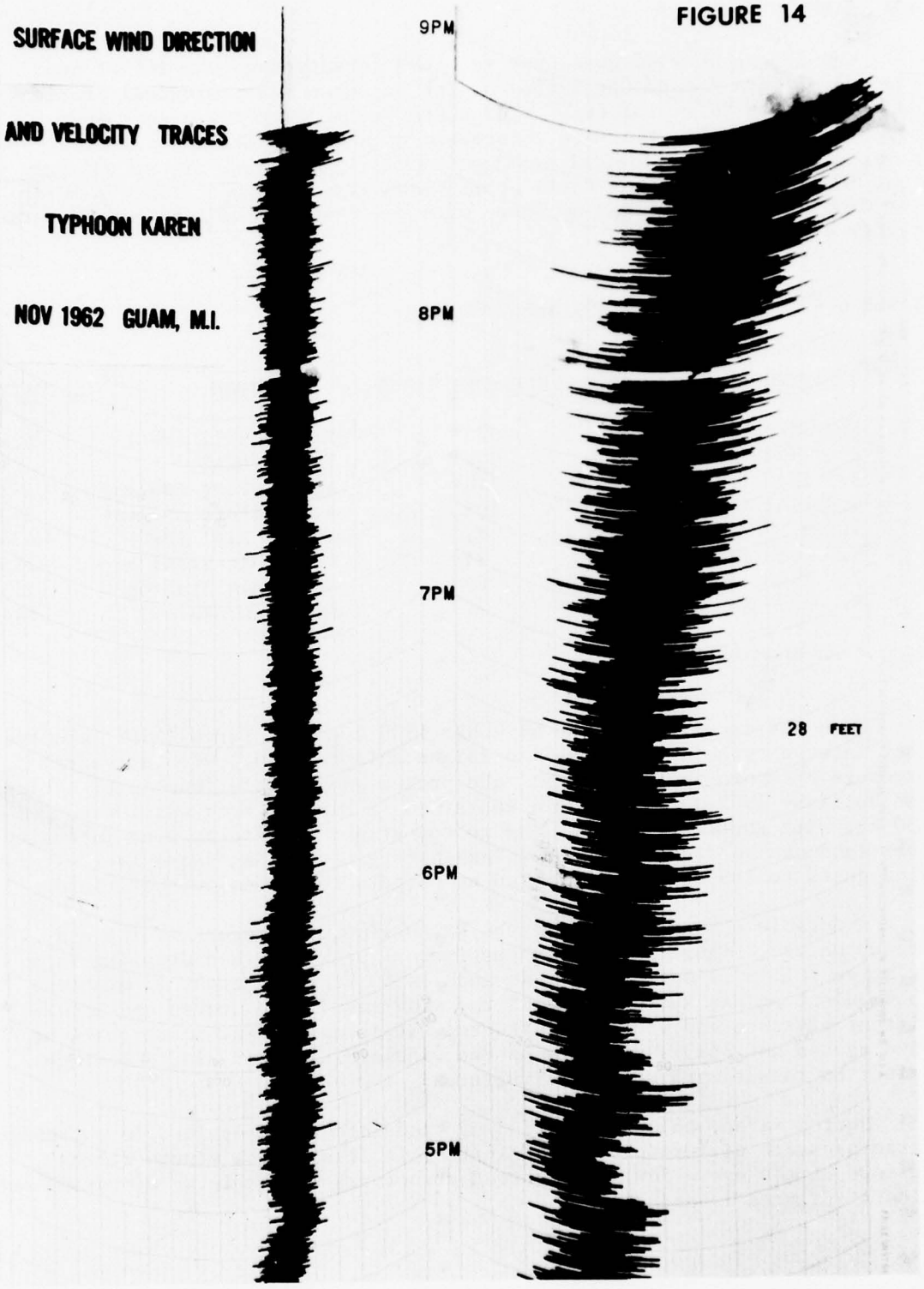

SURFACE WIND DIRECTION
AND VELOCITY TRACES
TYPHOON KAREN
NOV 1962 GUAM, M.I.
9PM
8PM
7PM
6PM
5PM
28 FEET

Figure 15 - Aftermath of typhoon Karen - Agana Heights (U. S. Navy Photo)

Figure 16 - Structural damage suffered by Talofofo church due to Karen's winds (photo by V. Olsen)

4.3 ATMOSPHERIC PRESSURE

Table 7 shows the minimum sea level pressures recorded on Guam for values less than 980.0 mb based on available records since 1900. Both the November 1900 typhoon and Karen 1962 caused unusually low pressures to be recorded. However, neither observation was made directly in the eye of the typhoon as both centers passed south of the meteorological stations. Thus the actual lowest pressure was not measured as the typhoons crossed Guam. In the case of Karen, the central pressure was estimated near 912 mb based on an interpolation of aircraft reconnaissance measurements shortly before and after landfall. Although such a low pressure is relatively infrequent even for typhoons, it is still considerably above the lowest sea level pressure on record. The lowest value was 876 mb, obtained by aircraft reconnaissance in typhoon June (November, 1975) while located 230 nm west of Guam (12.9N 143.2E).

TABLE 7 - SOME MINIMUM SEA LEVEL PRESSURE MEASUREMENTS ON GUAM

TYPHOON	PRESSURE (MB)	LOCATION	REMARKS
1. 1900 (Nov)	926.5	Agana	
2. Karen (Nov 1962)	931.9	Naval Air Station	Central pressure estimated at 912 MB
3. 1918 (July)	954.6	Agana (Agricultural Exper. Sta.)	In eye
4. 1940 (Nov)	955.6	Agana (Fort Apugan)	
5. 1941 (Aug)	969.9	Agana (Fort Apugan)	
6. Allyn (Nov 1949)	971.9	North Field	
7. 1946 (Sep)	972.4	Harmon Field	
8. 1876 (Dec)	974.9	Agana	
9. Olive (Apr 1963)	976.5	Nimitz Hill (FWC)	
10. Lola (Nov 1957)	978.1	Naval Air Station	

Figure 17 is the Fleet Weather Central barograph trace during typhoon Karen as the eye passed some 10 nm to the south. Based on the Naval Air Station reading (931.9 mb) at this point of closest approach, an extreme pressure gradient of 27 mb/nm existed over the southern portion of the island. Due to Karen's above normal rate of forward motion (17 kt) the pressure fell at a rapid rate. From a reading of 1000 mb at 1100L the pressure fell nearly 66 mb in 11-1/2 hours, a rate of 5.7 mb/hr. Between 2130L and 2230L the change was 29.0 mb/hr - a drop rarely recorded at a meteorological station. This sudden drop in pressure and extreme gustiness of the wind resulted in explosive action on reinforced concrete structures. "Window panes and/or entire louvered casements were forced outward, including doors and/or frames, particularly the French doors in living quarters" (FWC/JTWC, 1962).

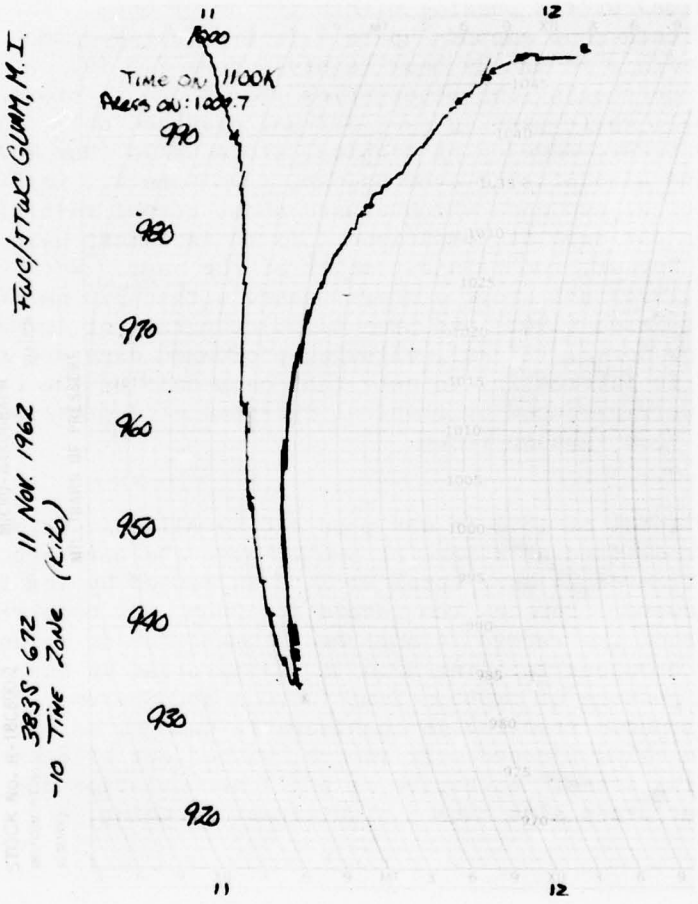


Figure 17 - FWC/JTWC Guam M. I. barograph trace for typhoon Karen 11 Nov 1962

4.4 RAINFALL

The amount of rainfall associated with the passage of a tropical cyclone can be highly variable, and is dependent on several factors. These include the rate of forward motion and the position of the rain gauge with respect to the cyclone's track. However, the highest rainfall measurements in tropical cyclones are usually recorded in mountainous regions. This results from orographic lifting, which increases the rate of ascent of the moisture laden air and augments the total rainfall. It should be noted that measurement of rainfall under typhoon conditions is difficult, as significant amounts are blown out of the rain gauge, with a loss as much as 50% possible (Dunn and Miller, 1960).

Figure 18 shows the frequency distribution of maximum 24 hour rainfall brought by tropical storms passing within 180 nm of Guam. The bulk of the cases (65%) indicate that amounts up to 4 in are fairly common during center passage with a median 24 hour rainfall near 2.5 in. As an example of some of the contrasting characteristics from storm to storm, typhoon Jean (April 1968), while passing over Saipan, produced only .33 in/24 hr at Guam. In contrast, developing tropical storm Carla (May 1974), on a similar track and also passing over Saipan, gave Guam 4.3 in/24 hr. Table 8 lists those tropical cyclones which caused above normal rainfall ($\geq$ 6 in) since 1946. For purposes of comparison, six in is almost half the mean total of 13.78 in for August, the rainiest month of the year. With the exception of Mary (August 1974) all storm centers passed within 120 nm of Agana. In all cases except Karen (1962) and Irma (1953) the rate of forward movement was near or below normal (11 kt), allowing prolonged exposure to the typhoon's rain bands. It is interesting to note that over half of the cases (7) of heavy rainfall were produced by tropical cyclones of depression or storm strength rather than typhoon force.

The highest total of 18.3 in was produced by Alice in October of 1953, while its center drifted at a rate of 5-6 kt over the northern end of the island. The estimated 24 hour total of 24.5 in caused by the typhoon of October 1924, however, remains the record for Guam. By comparison, this is still well short of the record 24 hour measurement for an island of relatively low terrain. A downpour totaling 42.4 in was recorded in Okinawa in September 1956 during passage of typhoon Emma (Jordan and Shiroma, 1959). Both Alice and 1924 typhoon resulted in considerable damage, as extensive runoff due to prolonged rains flooded over rivers, washed out bridges and inundated adjacent low lying areas. Excessive rainfall accumulation due to poor drainage in other areas also caused significant flooding.

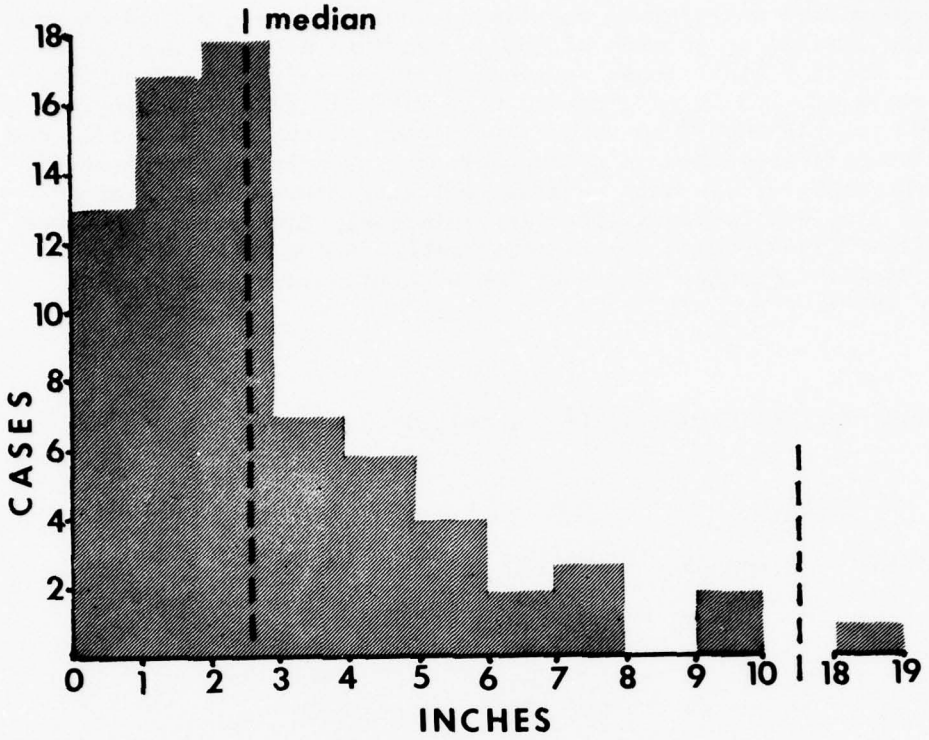


Figure 18 - Frequency Distribution of Maximum 24 hr rainfall occurring on Guam with Passage of Tropical Storm (≤ 180 nm) for Period 1948-1975.

TABLE 8 - MAXIMUM 24 HOUR RAINFALL TOTALS ON GUAM* (1946-1975)

TROPICAL CYCLONE		AMOUNT (IN)	LOCATION	CPA
T. S. ALICE	OCT 1953	18.30	Andersen AFB	N 15
TY AMY	MAY 1971	9.92	Taguac	SSE 90
T. S. IDA	OCT 1969	9.38	Taguac	NNE 80
T. S. IRMA	FEB 1953	7.88	Andersen AFB	S 90
T. D. POLLY	AUG 1971	7.81	Taguac	NNE 85
T. S. VIRGINIA	SEP 1965	7.48	Taguac	NE 130
T. D. MARY	AUG 1974	7.36	Taguac	NNE 130
TY NINA	AUG 1953	7.07	Andersen AFB	N 15
TY KAREN**	NOV 1962	6.32	Taguac	S 10
T. D. BABE	APR 1974	6.37	Taguac	E 40
TY SUSAN	DEC 1963	6.09	Taguac	N 75

* (1) Highest recorded rainfall on Guam occurred on 1 October 1924 approx 24.5 in/24 hr (Agana Agricultural Experimental Station).
(2) During 6 July 1918 typhoon 10.50 in/24 hr was recorded.

** Power to rain gauge failed during storm (observation taken day following center passage), which leads to possibility that significantly higher amounts (≥ 10 in) may have occurred during CPA.

The information on rainfall amounts accumulating in a period of an hour is quite limited as records of hourly readings are only available since 1957. Table 9 lists those tropical cyclones which caused one hour rainfall totals of 1.5 in or greater, with Virginia (1965) heading the list at 3.43 in. It should be noted that accumulations of up to 1 in per hr are occasionally recorded in rainshowers not associated with tropical cyclones. Records for one hour rainfall extremes are somewhat sketchy for cases of tropical cyclones affecting relatively flat areas. However, Dunn and Miller (1964), cite a 6 in accumulation for a period of 75 minutes at Hialeah, Florida in connection with passage of a hurricane (12 October 1947).

TABLE 9 - SOME MAXIMUM RAINFALLS ($\geq$ 1.5 in/hr)*

NAME	DATE	CPA	1 HR RAINFALL (IN)
T. S. VIRGINIA	13 Sep 65	NE 130	3.43
T. D. JOAN	25 Aug 59	N 130	2.82
T. S. EMMA	2 Oct 62	NNE 170	2.13
TY AMY	3 May 71	SSE 90	1.83
TY WENDY	27 Jul 63	SW 65	1.79
T. S. IDA	16 Oct 69	NNE 80	1.73

* All measurements recorded at National Weather Service Office, Taguac (1957-1975).

4.5 STORM SURGE

Inundation of low lying coastal areas by the sea has occurred during passage of severe storms near Guam. An inspection of narrative accounts since 1946 would indicate significant inundation should be expected (low lying coastal areas) with the passage of the center of a tropical cyclone of typhoon strength directly over or within 60 nm of the island. However, specific information on Guam storm surges is quite sketchy as little reliable documentation as to their extent and height are available. Another problem in documentation is separating the combined effect of flooding by rainfall runoff and surf with that of sea inundation alone.

Based on narrative reports, the southern coastline of Guam is quite susceptable to flooding by passage of typhoons as distant as 200 nm south of Agana. Reports of the Inarajan-Merizo road being awash have been frequent. Inarajan and Talofofo Bays have suffered from inundation with close passage of typhoons Allyn (1949), Lola (1957) and Karen (1962). During the November 1900 typhoon the village of Inarajan was swept away with the loss of 28 lives. In Merizo, water was reported 4-5 feet high during Lola (1957) with Cocos Island completely inundated by Allyn (1949). On the western coast, the village of Agat suffered severe damage by sea action during the September 1946 typhoon and Karen (1962). In Agana, major inundation has occurred at least twice this century due to the November 1900 typhoon and Karen (1962). During the 1900 typhoon, water reached the Plaza in front of the Palace (near the present site of Agana Cathedral) and Karen brought the sea in at least as far. During Karen the storm surge washed boats, docks and debris from Agana harbor several blocks inland, leaving fishing boats weighing several tons on Marine Drive (Figure 19 and 20), with sand deposits nearly a foot deep along the drive between Tamuning and Anigua. Probably the most catastrophic sea inundation on Guam was during the typhoon of November 1693 which engulfed and washed away all structures in Agana.

Figure 19 - Aftermath of typhoon Karen - Sea inundation in Agana with boats left high and dry inland from Marine Drive (photo by V. Olsen)

Figure 20 - Destruction of typhoon Karen with boat in background carried over a block inland by flooding from the sea (photo by V. Olsen)

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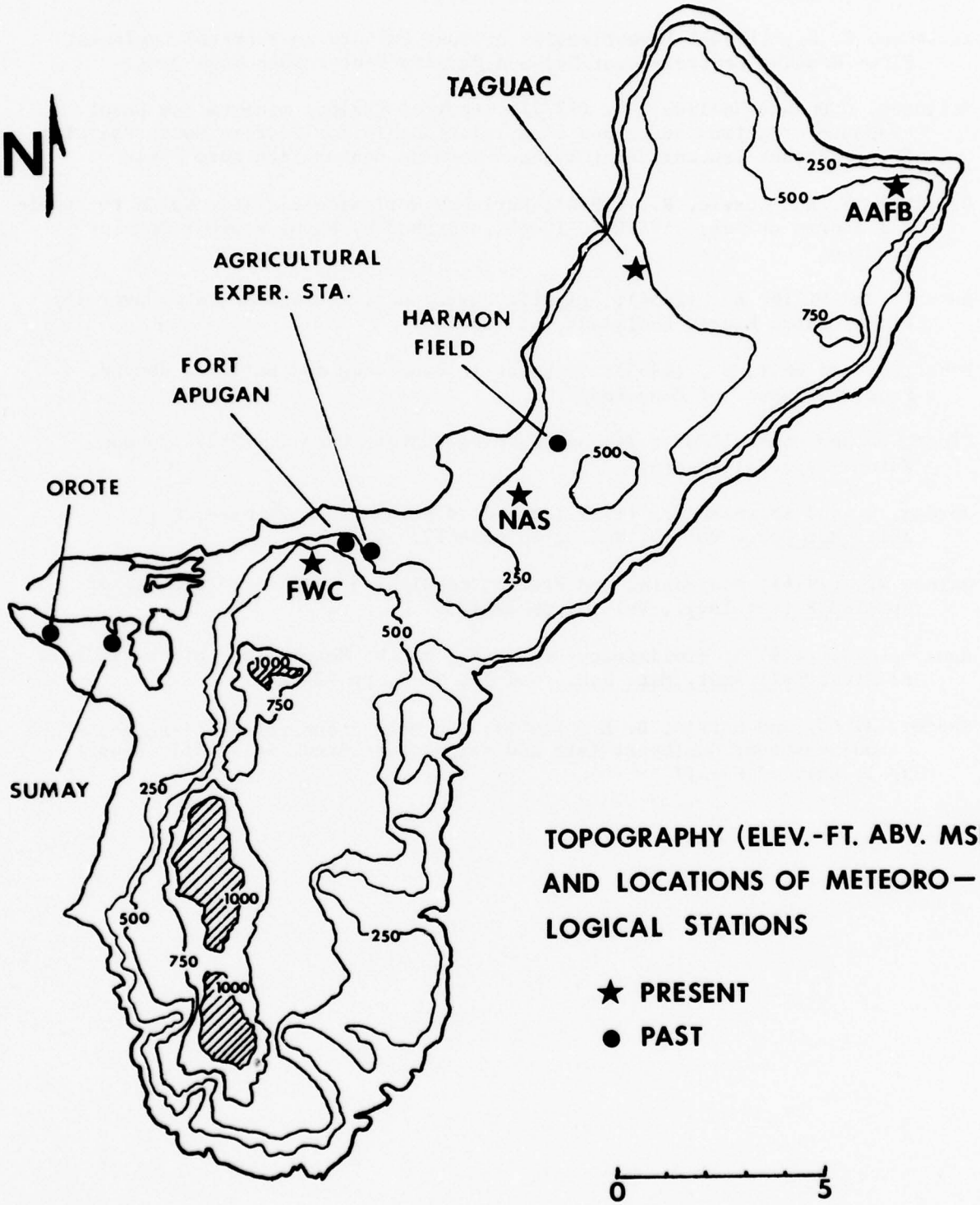


TOPOGRAPHY (ELEV.-FT. ABV. MSL) AND LOCATIONS OF METEORO-LOGICAL STATIONS

★ PRESENT

● PAST

APPENDIX A - SOME EARLY GUAM TYPHOONS

YEAR	DATE	REMARKS
1671	3 OCT*	First recorded mention of typhoon affecting Guam. "Eye passed directly over island, with most of the homes on the island toppled, as well as the church and the rectory suffering the same fate. A great many people were killed by falling debris and inadequate shelter while the damage to agricultural crops was a serious loss to the people."
1680	11 NOV	"A hurricane rose on the northern side on 11 November. Although storms were frequent in the islands, a more violent one had never been seen. It lasted two days and caused frightful disorder. Almost all the houses were toppled over, canoes smashed, trees and crops ruined. To add to the disaster, the sea became so swollen that the people were obliged to flee to the mountains."
1693	20 NOV	"In 1693 a terrible typhoon occurred. It began at dusk on the night of November 20 with a deluge of rain. The wind moved from north to south and whipped up the sea in such a manner that it seemed as if the island of Guam would be submerged. The sea broke its bounds and spread inland taking trees, houses and churches with it. Even the fortress at Agana toppled and was washed away. Those who saved themselves did so by taking refuge in the hills or by swimming about all through the night. Not a house nor building remained standing on the island. Inland from the shore the soil was covered with sand and stones left there by the subsiding sea."

Source: History of the Mariana Islands, by Father Charles Le Gobien, S. J., Paris, 1700 (translation at Micronesian Area Research Center, University of Guam)

* Date based on "The First Typhoon Recorded in Guam", translation of research by Father Paster, Guam Recorder, April 1938.

APPENDIX B - TYPHOONS AFFECTING GUAM DURING 1800's

YEAR	DATE	REMARKS
1807	7 APR	"All the houses destroyed by the strong typhoon."
1822	9 SEP	Strong typhoon affects Guam, Rota, Tinian and Saipan.
1824	11 NOV	No details.
1831	9 NOV	No details
1835	7 MAR	Typhoon affected Guam and Rota.
1842	26 SEP	No details.
1847	23 MAY	"A typhoon of horrible wind destroyed a greater part of the houses. No one killed."
1848	10 AUG	"Violent typhoon causing extensive damage, flood and famine."
1855	23 SEP	"A severe hurricane accompanied by earthquakes from time to time. All native wooden houses destroyed, those of stone and tile were dismantled. The fields and plants were as if burned, being without leaves or fruit."
1857	11 APR	No details
1859	17 APR	"Strong typhoon - a ship, although having two anchors, was thrown against the reef."
1860	18 NOV	No details.
1861	23-24 NOV	"Very strong typhoon."
1864	14 FEB	"Damage to roads and houses, crops lost due to salt spray."
1868	21-23 JUN	"Roofs of houses went off, but no casualties. One ship was thrown onto another in harbor."
1870	14 NOV	"Center passed north of island, many houses, roads and bridges damaged."

YEAR	DATE	REMARKS
1872	19 AUG	"Ship Maria del Rosario thrown onto reef, three drowned."
1873	24 JUN	"Rota, Tinian, Saipan suffered much damage."
1875	7 AUG	"Destroyed houses and plantations on Tinian and Saipan."
1876	2 DEC	Agana in eye at 1500L, minimum SLP 974.9 mb. "125 houses destroyed on island, many lost roofs in Agana."
1891	27 OCT	"Very strong typhoon which caused much damage, leper colony demolished. Center passage over island. The ship Yap was demolished and another ship lost."

Sources: Micronesian Area Research Center (MARC), University of Guam

1807-1842, 1848	(a) Records of the Spanish Colonial Government in the Mariana Islands (excerpts from file at U. S. Library of Congress).
1847, 1855-1860	(b) Cronica de las Islas Marianas, Fr. Aniceta Ibanez
1861-1891	(c) Cronica de las Islas Marianas, Fr. Francisco Resano

APPENDIX C - TYPHOONS AFFECTING GUAM 1900 - 1941

YEAR	DATE	REMARKS
1900	26-27	Buildings were demolished in Sumay, Agat, Merizo, and Inarajan with three bridges awash. Trees were uprooted or torn to shreds with extensive damage toll to all crops. In Apra Harbor the USS BRUTUS was torn from her moorings and blown upon the reef.
1900	13 NOV	Most severe typhoon since 1855 with center passing over southern portion of island. Pressure fell to 926.0 mb at Agana. "Agana and most of the other towns were laid in ruins, nearly all houses except of coral masonry being practically destroyed. In Agana the sea reached the Plaza in front of the Palace. A huge wall of water coming in from the sea overwhelmed the village of Inarajan, killing or drowning 28 persons." The station ship USS YOSEMITE (6000 tons) parted from her moorings and was driven upon the reefs of Apra Harbor, and later sank. Total of 34 deaths resulted from typhoon with the ruined crops being a severe economic loss.
1911	19 OCT	Center passed between Guam and Rota. Several native houses unroofed and several feet of bank along Agana beach were washed away. Some wharfs destroyed or badly damaged in Agana. Major damage sustained on Rota. Minimum pressure recorded on Rota was 946.5 mb.
1911	31 OCT	Center passed some distance south of Guam. Southern part of island affected most with many telephone poles downed. In Merizo, many houses were unroofed.
1912	26-30 AUG	Principal damage to crops by fringe effects of typhoon
1912	15-17 DEC	Principal damage to crops by fringe effects of typhoon.
1913	17-19 SEP	Center passed north of Guam. Fringe winds damaged copra crop.
1913	10 NOV	Center passed near Rota. Minimum pressure measured at Rota was 940.1 mb, while Agana recorded 983.4 mb. Many trees and telephone poles downed and houses unroofed on Guam. Storm waves washed away Agana waterfront wharf. Several sampans were sunk or beached at Agana and all low lying areas of town were flooded.
1914	7 JUL	Center passed north of Guam. Winds gusted near typhoon force and seas in Apra Harbor were the heaviest in years. Damage to crops, buoyage, and boat channels were considerable.

YEAR	DATE	REMARKS

1915 8 OCT Center passed over Rota with a minimum pressure recorded at 925.2 mb. Although having little effect on Guam, Rota suffered considerably. A crust of salt from the ocean spray covered Rota's fields severely affecting crops, and later resulting in near famine conditions due to lack of rain during following six months.

1915 2-3 SEP Gusty winds and heavy rains from fringe of typhoon. Considerable damage done to standing crops in the northern part of the island.

1918 6 JUL Eye passed directly over Agana with a calm lasting one hour. Minimum pressure recorded in the center was 954.0 mb. Six persons were killed, thousands of persons were left homeless and property valued at many thousands of dollars received considerable damage. Hundreds of native homes were overturned while more substantial structures were either unroofed or demolished. A heavy toll was also taken in terms of the numerous telephone and power poles as well as coconut trees downed. Crop losses were considered enormous.

1918 17 SEP Gusty winds and heavy rains from fringe of typhoon passing to northeast of island. Some minor crop damage was sustained.

1919 20-21 AUG Center passed some distance south of the island with a minimum pressure of 991.2 mb recorded at Agana. Only minor crop damage reported.

1923 26 MAR Center of slow moving typhoon passed south of island with a minimum pressure of 982.0 mb (26th) and a maximum 24-hour rainfall of 4.84 (27th) recorded at Sumay. Winds gusted well over typhoon force with the majority of the damage confined to the southern portion of the island. Bridges and roads were washed out with evidence of the sea washing for distances of a quarter of a mile inland plentiful. Several native houses were swept from their foundations, and all communication lines were downed. No loss of life was reported.

1924 1 OCT Center of typhoon passed south of Guam with winds gusting near 60 kt over southern portion of island. Minimum pressure at Sumay was 999.7 mb. Extreme rainfall occurred during passage with as much as 19 in in 15 hr and 28.25 in within 30 hr being recorded on the island. A total of 33.09 in accumulation in 48 hr was measured (all values at Agricultural Experimental Station Agana). The resulting floods caused one death and the destruction of 50 buildings and a loss of hundreds of thousands of dollars. Rivers overflowed their banks sweeping away native houses, sections of roads and bridges.

1925 30 AUG Fringe of typhoon passing south of island, minimum pressure 992.2 mb recorded. No details available.

YEAR	DATE	REMARKS

1925 25 OCT Center of typhoon passed south of island with a minimum pressure of 991.5 mb recorded at Agana. Heavy waves washed along the southern coast between Inarajan and Merizo damaging roads, and wrecking bridges. Strong gusty winds were responsible for downing hundreds of trees and unroofing several houses around the southern coast.

1930 4 AUG Center of typhoon passed some distance northeast of the island. Minimum pressure of 996.6 mb was measured at Sumay with winds gusting to 36 kt and a maximum 24 hr rainfall of 4.48 in. No further details available.

1935 3 DEC Center of typhoon passed southwest of island. Minimum pressure of 998.3 mb with gusts to 60 kt were recorded at Agana. Considerable damage was reported to trees and crops but only slight damage to structures.

1940 8 JUL Center passed southwest of island. Wind gusts to 53 kt and a minimum pressure of 1001.7 mb were recorded at Agana. No significant damage reported.

1940 3 NOV Most severe typhoon since 1918. Eye estimated to have passed near southern end of island with minimum pressure of 955.6 mb recorded at Agana (1400L). Wind gusts were estimated to have reached 130 kt. Damage was heavy, in the hundreds of thousands, with one death recorded. Almost all structures on the island were either unroofed or entirely destroyed leaving thousands homeless. Hundreds of trees were downed as the strong winds took a heavy toll on planted and natural crops.

1941 3 AUG Eye of typhoon passed off northern end of the island. Minimum pressure of 969.9 mb (1230L) and a wind gust to 108 kt was recorded at Agana. A maximum 48 hr rainfall total of 12.42 in was measured during passage. Most of structural

damage was to roofs with no casualties reported. Telephone, electricity lines and many large trees were downed. Rain damage was extensive as many rivers overflowed inundating nearby houses and washing out sections of roads. This typhoon, however, was not as severe as one in November 1940.

Sources:	Period 1900-1941
1900	(a) The Guam Recorder
1911-1919	(b) The Guam Newsletter
1923	(c) "Typhoon at Guam, M. I., March 19-27, 1923" by West and Swartout, Monthly Weather Review, September 1923
1924-1941	(d) The Guam Recorder
Rota Typhoons	(e) Chronicle of Father Corbinians (translation at Micronesian Area Research Center, University of Guam)

APPENDIX D - TROPICAL STORMS/TYPHOONS AFFECTING GUAM 1945-1975

YEAR	NAME	DATE	REMARKS
1946	-	21 SEP	Eye of 90 kt typhoon passed midway between Rota and Guam with peak gusts estimated at 85 knots affecting Guam. Extensive damage was caused to temporary buildings with many quonset huts demolished. At Orote Point Naval Air Base 70% of the aircraft sustained damage while the barracks, BOQ and repair building were almost demolished. At Harmon Field several large hangars received damage. Village of Agat was one of the most badly affected by the typhoon with 30 houses destroyed, and 30 others seriously damaged. In spite of havoc only one injury was reported. Rota received the brunt of the typhoon with trees, crops and all buildings flattened.
1948	AGNES	14 NOV	Center of storm developing to typhoon strength passed just south of Rota. Winds gusting up to 55 kt occurred on Guam but no significant damage reported on either Guam or Rota. One casualty was sustained on Saipan.
1949	ALLYN	17 NOV	Eye of severe typhoon (135 kt near center) passed 60 nautical miles south of island bringing wind gusts well over 100 kt to the island. A total of $19.1 million in damage was caused to military and non-military property. Camp Witek, a Marine base on the south-east coast received 75% damage to its temporary installations. Severe damage to native houses and crops occurred in the southern section of the island. A total of 2500 homes were damaged, and in the town of Inarajan, 60% were totally destroyed by inundation from the sea. Four major bridges were destroyed and 55% beyond use. Although several injuries were reported, no casualties occurred.
1950	DORIS	9 MAY	Typhoon with center winds of 120 kt passed 135 nautical miles southwest of Agana with gusts of 63 kt recorded on the island. Damage was slight with a two-foot flood reported in Inarajan, and high waters washing out sections of road between Inarajan and Merizo.
1951	MARGE	11 AUG	Center of tropical storm passed 25 nautical miles south of Agana with peak gusts of 55 kt occurring on the island. Some 4 in of rain fell within a four hour period (NAS); however, no significant damage by the gusty winds or heavy rains was reported.
1952	HESTER	31 DEC	Eye passed 120 nautical miles south of Guam with center winds of 95 kt with gusts to 70 kt sustained on the island. The southern end of the island reported minor damage with only a few houses destroyed. However, scores of trees were uprooted or broken off, and both the vegetable and fruit crop was lost. Heavy seas caused both the Talofofo and Ylig river bridges to be awash and several small craft were sunk at the commercial port.

YEAR	NAME	DATE	REMARKS

1953 IRMA 22 FEB Center of tropical storm (60 kt center winds) passed 90 nautical miles south of Agana with gusts of 55 kt reported on the island. Six in of rain was recorded in 15 hr (NAS). Only minor damage was reported to trees and crops.

1953 NINA 10 AUG Center of developing typhoon (center winds of 65 kt) passed just offshore of the northern tip of the island with highest gust reported on the island of 57 kt. No significant damage reported with exception of uprooted trees, and high seas awash over Inarajan road and Talofofo bridge.

1953 ALICE 14 OCT As a developing tropical storm (35 kt), Alice passed just offshore of northern tip of island. Peak gust recorded on the island was 56 kt on the 15th. Between the 14th and the 16th, Alice drifted only 270 miles subjecting Guam to prolonged periods of torrential rains which resulted in the heaviest rainfall since the typhoon of October 1924. In a period of 24 hours (14/1000L-15/1000L) Andersen Air Force Base recorded 18.87 in, and NAS 15.48 in. During a 48-hr period (14th-16th), 32.51 in fell at Andersen Air Force Base, while NAS totaled 21.21 in. Also a severe electrical storm accompanied the passage of Alice with lightning striking Andersen Air Force Base three times, with two airmen burned. The near-record rains resulted in significant flooding with rivers overflowing washing away four bridges, isolating southern communities, and causing four drownings. Behind Marine Drive in Tamuning, all homes were inundated with depths of three to four feet reported. Large sections of Naval Station and Andersen Air Force Base were also reported under water. Property damage was estimated well in excess of $100,000.

1954 LORNA 14 SEP Center of developing typhoon (70 kt) passed 180 miles north of Guam, causing wind gusts of 50 kt to affect the island. No significant damage was reported.

1957 LOLA 16 NOV Eye of severe typhoon (130 kt center winds) passed 40 nautical miles south of Agana, bringing wind gusts of over 100 kt to southern portion of island. Estimates of civilian and military loss were placed near $5 million. Damage from the wind in the northern part of the island was mainly confined to stripping roofing material from structures and broken windows; however, several elephant quonset huts were blown down (one at NAS and several in Anigua). In the southern sector of the island scores of structures were unroofed or collapsed. High seas inundated sectors (particularly Inarajan) along the southern coast with wave action damaging homes and toppling trees, while leaving portions of roads and bridges awash. Several rivers on the island overflowed and inundated nearby homes. No casualties were reported.

YEAR	NAME	DATE	REMARKS

1961 NANCY 11 SEP Eye of severe typhoon (130 kt center winds) passed 125 nautical miles south of Agana with peak winds estimated at 50 kt over southern end of island. Roads were damaged by sea action along the southern coast and 50% of crops in southern sector of island were destroyed. The northern end of the island suffered little damage. No casualties were reported.

1962 KAREN 11 NOV Worst typhoon to strike island since 1900. The eye of severe typhoon (center winds 130 kt) passed over southern end of island between Talofofo and Umatac. (Although appeared headed for Rota, during last six hours before CPA, Karen took a 20° shift to the west). Wind gusts were estimated to have reached 150-160 kt over sections of the island. Approximately $250 million in damages were sustained. Ninety-five percent of all homes were destroyed on the island, leaving 9000 homeless, 100 injured, and 9 dead. At Andersen Air Force Base some 180 buildings were destroyed, while at the Navy station 80% of the Ship Repair Facility buildings suffered moderate to severe damage. Other naval buildings sustained minor to major damage with many quonset hut structures collapsed and others were wrenched from their moorings. At Apra Harbor, three ships were sunk while two tug boats and a huge floating crane were driven ashore. The sea inundated Marine drive depositing boats from the Agana boat basin as far as one block inland. The following vivid description of the damage extent is extracted from the official Fleet Weather Central report on Karen: "The central portion of the island exhibited the eerie appearance of being completely denuded. Snapped and uprooted palm trees and shrubs liken the area to the scorched efforts of a forest fire. Bark was stripped off tree trunks and branches as if they had been sandblasted. Utility poles followed the same destructive pattern as poles were snapped like match sticks."

1963 OLIVE 29 APR One of the few typhoons approaching Guam from the south. The eye of this major typhoon (center winds 105 kt) passed 35 nautical miles west of Agana at a slow pace (5-7 kt). Peak gusts of 85 to 90 kt were experienced on the island. Temporary structures (quonset huts and wooden buildings) received severe damage or were destroyed in certain sectors of the island. In total 120 homes were destroyed, 1140 severely damaged, while some 60 commercial buildings were partially demolished. As a result at least 1000 people were left homeless. Flooding by the sea was experienced in Inarajan, Merizo and Anigua. Several bridges were also awash (particularly the one over Ylig River). Total damage was estimated at $5 million with ruined agricultural crops accounting for 20% of total. No casualties were reported. The center of the typhoon shifted to a northeasterly track after passing Guam. Later the eye crossed directly over Saipan on the 30th, with wind gusts estimated near 120-130 kt. Ninety-five percent of houses were badly damaged, power-lines destroyed, water system inoperative, new hospital roof, supply and public works center badly damaged. Total damage to public and private sectors were estimated near $4.4 million.

YEAR	NAME	DATE	REMARKS

1963 WENDY 11 JUL Eye passed 65 miles southwest of Agana with center winds of 85 kt,causing wind gusts of 50 kt to affect the island. Fortunately, storm was of small areal extent or significantly higher winds would have been expected. Damage was confined mainly to crops.

1963 SUSAN 24 DEC Fourth major typhoon to pass within 180 nautical miles in 13 months. Eye tracked north of Rota or 70 nautical miles from Agana with center winds of 95 kt. Wind gusts of 70 kt were estimated to have affected the northern tip of the island. No significant damage was reported on Guam. However, moderate damage was reported in Rota, Tinian and Saipan homes suffering from 25% to 90% damage.

1964 SALLY 5 SEP Center of developing typhoon (60 kt) crossed near southern tip of island bringing wind gusts estimated near 70 kt over southern end of Guam. Several homes in southern villages were unroofed while scores of trees were downed. Some sea inundation was reported at Talofofo Bay. Majority of monetary damage was in farm crop loss.

1967 GILDA 13 NOV Eye of major typhoon (center winds 100 kt) passed over Rota or 55 nautical miles north of Agana bringing wind gusts of 60 kt to northern end of island. Winds were strong enough to destroy a large bulk of the crop production but no significant structural damage. Heavy damage was reported on Rota as some 100 buildings were demolished, resulting in 500 homeless and eight injuries, but no deaths.

1968 JEAN 11 APR Eye of severe typhoon passed 95 nautical miles north-northeast of Agana with center winds of 120 kt. A gust to 50 kt was recorded on the northern tip of the island. No significant damage was sustained on Guam. Jean, however, devastated Saipan with wind gusts estimated at 140-150 kt with 90% of the island's housing destroyed leaving thousands homeless, and an estimated total damage of $16 million. In spite of the damage, only one person was severely injured, and no deaths were reported.

1968 IRMA 22 OCT Center of developing tropical storm (45 kt) passed just south of Rota or 50 nautical miles north of Agana. Peak wind gusts of 65 kt swept the northern tip of Guam; however, no significant damages were reported. Some minor to moderate damage occurred on Rota and Saipan.

YEAR	NAME	DATE	REMARKS

1968 JUDY 27 OCT Eye of major typhoon (105 kt) passed 100 nautical miles south of Agana. Peak gusts of 50 kt were experienced on the island; however, no significant damage was reported.

1968 ORA 23 NOV Center of fast-moving (20 kt) tropical storm passed directly over Agana accompanied by wind gusts as high as 75 kt occurring over northern portion of the island. Damage was limited to loss of power on island, some broken windows and downed trees. The roof at the Santa Barbara School in Dededo was reported caved in. Heavy rains temporarily caused some rivers to overflow and flood bridges.

1969 PHYLLIS 22 JAN Center of weakening but fast-moving (20 kt) tropical storm passed over Agana with brief gusts of 45-50 kt experienced over northern portion of island. Rainfall from system was quite light (.48 in in 24 hours). No damage reported.

1971 AMY 3 MAY Eye of severe typhoon (120 kt) passed 90 nautical miles southwest of Agana. Amy's progress between the 3rd and 4th was slow (6 kt), causing prolonged gales (gusts to 60 kt) and heavy rain to affect the island with a total amount of 15.21 in in 48 hr. Sea inundated several sections in southern portion of island with Inarajan reporting significant flooding and several sections of road being washed out. Damage estimates were placed near $902,000 with 80% accounted for by wind damage to crops.

1974 MARY 11-13 AUG Mary's center was located some 450 nautical miles to the northeast. However, her circulation was characterized by maximum wind bands far removed from the low pressure center. Winds gusting to gale force occurred over a period of 3 days with gusts peaking near 55 kt on the 12th and 13th. Record rainfall amounts occurred for August (since 1945) with 7.25 in/24 hr as Guam lay beneath Mary's persistent outer rain bands. The persistent strong southwesterly winds were responsible for significant damage to marine interests on Guam. The CARIBIA (a 40,000 ton passenger liner being towed to Taiwan for salvage) was cut loose from her tug at the entrance to Apra Harbor, ran aground on the breakwater, and sank ($3.3 million loss). The heavy seas also took their toll on small craft (which are normally protected on the leeward side of the island in the trades) as many broke their moorings and went aground. One yacht valued at $250,000 was included among the lost vessels. Some flooding by the sea was reported around the southern and western coasts from Merizo to Tamuning. Two lives were lost due to drowning and damage estimates amounted to over $542,000.

YEAR	NAME	DATE	REMARKS
1975	JUNE	19 NOV	Eye of severe typhoon (center winds 160 kt) passed within 215 nautical miles west-southwest of island causing wind gusts up to 70 kt (Andersen Air Force Base). Wave action inundated several sections of the seacoast highway between Merizo and Umatac while sections of road between Ylig Bridge and Talofofo were blocked by backed up drainage water and debris. Wind accounted for most of the damage with apparent tornadic effects experienced in the central part of the island. Mangilao was hardest hit with several homes destroyed and some structures unroofed. This severe damage appeared to be confined to a narrow path which extended westward towards Tamuning, with several other structures along the way receiving damage in addition to downed power poles, and some cars blown from their parked positions. Estimated total damage was near $1.3 million with 38% accounted for in crop loss. Twenty-nine persons were left homeless but no deaths were reported.

YEAR	NAME	DATE	REMARKS
1976	PAMELA	21 MAY	Most severe typhoon to effect Guam since Typhoon Karen of 1962. Slow progression of Pamela across the island (eye passage - three hours) rendered Pamela more destructive than Typhoon Karen. Winds in excess of 100 kt were observed for 6 hours; typhoon force winds for 18 hours; and winds in excess of 50 kt for 30 hours. Despite extensive preparation, damage to both civilian and military facilities was estimated near $500 million; however, only one death was recorded. Estimated peak winds (sustained) were 120 kt with gusts to 145 kt. NWS Taguac recorded 33 inches of rainfall during Pamela's passage, with 27 recorded in a 24 hour period. Ten small ships and tugs which sought refuge in Apra Harbor either sank or ran aground. After passage, Pamela continued on a northwesterly track at an average speed of 10 kt and maintained her 120 kt intensity for an additional 36 hours.

APPENDIX E

TROPICAL CYCLONES ($\geq$ 34 KT) PASSING $\leq$ 180 NM OF AGANA, GUAM

Column 1: Name of cyclone
Column 2: Date (GMT) of closest point of approach
Column 3: Closest point of approach from Agana (nm)
Column 4: Estimated maximum sustained (one-minute) surface wind speed (kt) near center
Column 5: Estimated central minimum sea level pressure (mb) of cyclone
Column 6: Peak gust (kt) and direction observed on Guam
Legend: + Anemometer failed, nf (North Field), h (Harmon Field), n (Naval Air Station), a (Andersen AFB), nh (Nimitz Hill)
Column 7: Minimum sea level pressure (mb) observed on Guam during passage
Legend: Same as in Column 6
Column 8: Duration (hrs) of gusts to gale force ($\geq$ 34 kt) (Andersen AFB unless otherwise specified)
Column 9: Maximum 24-hour rainfall observed on Guam - North Field 1946-49, Andersen AFB 1950-56, Taguac 1957-75
Column 10: Direction and speed of movement at CPA
+ Displayed a directional change of >45° to right of track within 300 nautical miles of CPA (++) to left of track (+++) - 90° within 180 nautical miles

1	2	3	4	5	6	7	8	9	10	REMARKS
Unnamed	21 Sep 46	N 26	90	955	82+ WSW(n)	972h	25	4.68	WNW 13	
					1947 NONE					
PEARL	01 Jul 48	SW 170	35	997	37 SSE(n)	1002n	8	1.21	WNW 15	
PAT	27 Oct 48	N 115	35	997	39 SW(a)	1003nf	3	2.23	WNW 15	
AGNES	14 Nov 48	NNE 40	60	980	65 N(a)	987nf	18	4.90	WNW 15	
HESTER	24 Jul 49	NNW 120	55	985	44 SW(n)	1002nf	1	2.03	Looped	
ALLYN	17 Nov 49	S 60	135	909	80+ ENE(n)	972nf	37	4.33h*	WNW 12	*16th
								1.57n*		*17th

1	2	3	4	5	6	7	8	9	10	REMARKS
DORIS	09 May 50	SW 135	120	922	63 SE(a)	998n	26	3.74	NW 11	
KEZIA	05 Sep 50	N 135	35	997	38 SSW(a)	1002a	<1/2	1.33n	Stalled	
MARGE	11 Aug 51	S 25	55	983	55 ENE(n)	996n	9	2.51	WNW 8	
THELMA	27 Oct 51	NNE 120	65	978	40 SE(a)	1009a	5	.39	WNW 20	
BESS	09 Nov 52	N 50	35	997	N/A	N/A	N/A	2.92	WNW 16	
HESTER	31 Dec 52	S 120	100	945	70 E(a)	996a	27	2.17n	W 22	
IRMA	21 Feb 53	S 90	55	985	55 SE(a)	1006a	15	7.88	WNW 15	
NINA	10 Aug 53	N 15	65	976	57 S(n)	982a	20	7.07	NW 12	
ALICE	15 Oct 53	N 15	35	997	56 S(a)	1001a	9	18.33	W 6+	Turn at CPA
IDA	24 Aug 54	SSW 70	35	997	44 S(a)	1001a	8	1.60	W 16	
LORNA	14 Sep 54	N 180	70	975	50 W(a)	997a	9	2.33	W 10+	
TILDA	26 Nov 54	S 80	45	990	38 E(n)	1006a	4	1.58	W 9	
					1955 NONE					
					1956 NONE					
VIRGINIA	19 Jun 57	S 100	45	993	43 SE(n)	1005n	2	.79	WNW 16	
FAYE	18 Sep 57	SSW 135	105	941	35 E(a)	1007n	3	.83	WNW 9	
HESTER	05 Oct 57	E 25	55	987	45 SW(a)	993n	3	3.97	Approach fm S turned NW after CPA++	
JUDY	21 Oct 57	N 125	55	985	29 WSW(n)	N/A	-	3.48	W 13+	
KIT	07 Nov 57	SSW 125	45	985	N/A	N/A	N/A	2.90	WNW 21	
LOLA	15 Nov 57	S 40	140	900	84+ NNE(n)	978n	34	5.61	WNW 12	
PHYLLIS	28 May 58	SW 170	105	940	37 SSE(a)	1006n	1	.91	NW 11+	
VIOLA	08 Jul 58	SW 65	60	982	42 SE(n)	N/A	1	1.92	NW 8	
GRACE	29 Aug 58	SSW 155	35	997	36 ESE(n)	N/A	N/A	.22	WNW 8	
IDA	20 Sep 58	S 20	35	998	46 E(n)	999n	6	1.75	W 17	
DINAH	16 Oct 59	SSW 125	90	953	42 N(n)	1000n	5	1.01	WNW 20	
EMMA	06 Nov 59	SSW 120	45	993	35 NE(n)	995n	<1/2	2.27	WNW 10	
MAMIE	15 Oct 60	NE 175	40	996	32 WSW(n)	N/A	-	.54n	NW 11+	

1	2	3	4	5	6	7	8	9	10	REMARKS
NANCY	10 Sep 61	S 95	130	910	59 SSE(nh)*	995n	25	3.68	WNW 15	*44a 43n
VIOLET	05 Oct 61	NNW 170	65	980	34 SW(n)	N/A	<1/2	1.59	Button hook at CPA ++	
BILLIE	23 Oct 61	SW 175	35	995	39 ENE(a)	1001n	8	2.73	Parabolic track at 180 nm radius +	
GEORGIA	19 Apr 62	WSW 160	85	956	39 SE(n)	1001n	<1/2	1.77	Approach from SW, turn at CPA to NNW+++	
RUTH	14 Aug 62	NE 100	40	993	34 NW(n)	N/A	-	1.75	N 7	
EMA	02 Oct 62	NNE 170	55	985	46 W(n)	1001a	8	3.41	Stalled	
KAREN	11 Nov 62	S 10	135	908	125+ N(nh)	932n	28	6.32*	W 17	*measured on 12th
NADINE	08 Dec 62	N 15	45	990	45 E(a)	991n	1	2.77	ENE 7	
OLIVE	29 Apr 63	W 35	35	932	87 SW(nh)	977nh	52	4.86	N 7+	
WENDY	11 Jul 63	SW 80	80	947	50 E(nh)	999n	26	3.17	SW 6 +++ NW9	
LOLA	13 Oct 63	W 30	30	996	35 WSW	998a	2	4.24	Loop W	
SUSAN	24 Dec 63	N 75	75	948	61 W(a)*	992a	36	6.09	WNW 12	*Site evac
TESS	20 May 64	NW 180	65	978	35 WSW(a)	997a	<1/2	2.03	NE 21	
ALICE	27 Jun 64	SW 50	45	993	32 ESE(n)	1005n	--	.55	WNW 8+	Dropped to TD 360 nm NW
SALLY	05 Sep 64	S 10	65	976	54 ESE(a)	998n	8	2.08	WNW 20	
WILDA	18 Sep 64	NNE 165	35	997	N/A	N/A	N/A	N/A	NW 6	
HARRIET	22 Jul 65	SW 30	35	995	40 S(a)	999n	10	3.75	Approach from SSW, turn W at CPA +++	
VIRGINIA	13 Sep 65	NE 130	40	992	35 SW(a)	1005a	--	7.48	NW 10	
BESS	28 Sep 65	NNE 150	45	998	41 SW(a)	1001a	3	2.54	WNW 9+	
FAYE	20 Nov 65	S 175	35		35 E(a)	1006n	5	1.67	W 16	
JUNE	22 Sep 66	W 145	45	988	36 S(a)	N/A	N/A	2.18	+++	90° turn SW of Guam
THERESE	20 Mar 67	NNW 90	35	998	30 S(a)	1001a	--	1.72	ENE 12	Parabolic track
DINAH	17 Oct 67	S 40	35	997	30 E(a)	1005n	--	1.68	W 10 ++	about Guam
GILDA	13 Nov 67	NNE 55	100	945	60 NW(a)	981a	46	5.09	WNW 10	
HARRIET	19 Nov 67	NNE 100	65	978	30 SE(a)	1007a	--	1.55	WNW 11	

1	2	3	4	5	6	7	8	9	10	REMARKS
JEAN	11 Apr 68	NE 95	115	935	54 NNW(a)	999a	44	.33	NW 9+	
LUCY	27 Jun 68	NNW 130	35	998	27 ENE(a)	N/A	--	.90	WNW 19	
MARY	21 Jul 68	NE 155	40	994	41 S(a)	N/A	<1/2	2.68	NW 9	
WENDY	29 Aug 68	NNE 130	85	950	N/A	N/A	N/A	.79	Stalled	
AGNES	02 Sep 68	N 180	75	965	37 SW(a)	N/A	<1/2	1.30	WNW 11	
IRMA	22 Oct 68	N 30	50	985	66 W(a)	989a	31	4.82	Turned from W to N+++	
JUDY	27 Oct 68	S 100	105	937	50 E(a)	1005n	13	.76	WNW 13	
KIT	01 Nov 68	E 95	50	985	41 NW(a)	1002n	<1/2	.29	NNW 8	
ORA	22 Nov 68	0	55	988	77 NE(a)	988n	8	3.18	WNW 20	
PHYLLIS	22 Jan 69	0	35	1000	55 SE(a)	1000a	1	.48	W 20	
IDA	16 Oct 69	NNE 90	35	998	36 S(a)	1006a	--	9.38	NW 6+	
PATSY	15 Nov 70	NW 90	50	987	21 W(a)	1003a	--	2.72	WSW 12	
AMY	12 May 71	SSW 90	120	920	60 E(a)	998nh	43	9.92	WNW 9+	
ROSE	09 Aug 71	NW 90	35	1000	24 NE(a)	1006a	--	1.63	WNW 10	
FAYE	06 Oct 71	N 125	55	992	36 SE(a)	1002a	3	2.18	W 27	
RITA	07 Jul 72	S 170	35	998	40 SE(a)	1005n	<1/2	2.97	W 7+	
BETTY	10 Aug 72	NE 150	50	985	18 NE(a)	1006a	--	1.05a	NW 13++	
					1973 NONE					
CARLA	03 May 74	NNE 105	45	989	35 NNW(a)	1005a	<1/2	4.39	WNW 8+	
POLLY	26 Aug 74	NNE 150	45	991	35 SW(n)	1001a	<1/2	5.14	Stalled	
NANCY	01 May 76	NW 80	35	1000	16 SW	1007	N/A	N/A	SW 12	T.S.-T.D. at CPA
PAMELA	21 May 76	0	120	930	126	932	25	27in	NW 17	Typhoon-Typh at CPA
SALLY	24 Jun 76	SW 178	35	999	35 SE	1009	N/A	N/A	NW 14	Typhoon-T.S. at CPA
THERESE	13 Jul 76	NE 140	130	913	23 NW	998	N/A	N/A	NW 16	Typhoon-Typh at CPA
BILLIE	04 Aug 76	NW 105	50	988	28 SW	1001	N/A	N/A	SW 14	Typhoon-T.S. at CPA
FRAN	05 Sep 76	SW 30	50	985	39 SE	992	N/A	N/A	NW 13	Typhoon-T.S. at CPA
GEORGIA	12 Sep 76	S 45	35	995	22 ENE	997	N/A	N/A	WSW 12	T.S.-T.S. at CPA
LOUISE	31 Oct 76	SSW 182	45	993	37 ESE	1006	N/A	N/A	WNW 14	Typhoon-T.S. at CPA

APPENDIX F

TROPICAL CYCLONES ($\geq$ 34 KT) PRODUCING GUSTS TO GALE FORCE ($\geq$ 1 HR) BUT PASSING OUTSIDE OF 180 NAUTICAL MILES OF GUAM

Column 1: Name of cyclone
Column 2: Date (GMT) of closest point of approach
Column 3: Closest point of approach from Agana (nm)
Column 4: Estimated maximum sustained (one-minute) surface wind speed (kt) near center
Column 5: Estimated central minimum sea level pressure (mb) of cyclone
Column 6: Peak gust (kt) and direction observed on Guam: n (Naval Air Station) a (Andersen AFB)
Column 7: Duration (hrs) of gusts to gale force ($\geq$ 34 kts)

1	2	3	4	5	6	7	REMARKS
JEAN	21 Dec 47	SSW 300	45	990	43 ENE(a)	2	
KIT	28 Jun 53	SW 345	85	956	35 E(a)	3	
TILDA	16 Apr 59	SSW 230	105	938	38 ENE(n)	4	
OPHELIA	30 Nov 60	SSW 200	80	965	39 E(n)	2	
OPAL	11 Dec 64	SW 410	65	977	43 E(n)	1	
OLGA	28 Jun 70	SW 240	35	997	42 E(a)	3	
MARY	12 Aug 74	NE 455	40	989	57 SW(a)	67	Max 24-hr precip 7.36 in at Taguac (t)
GLORIA	04 Nov 74	SW 450	55	983	43 SE(a)	4	
JUNE	19 Nov 75	WSW 215	155	885	70 SE(a)	25	Max 24-hr precip 3.16 in (t) Min SLP 997.1(n)

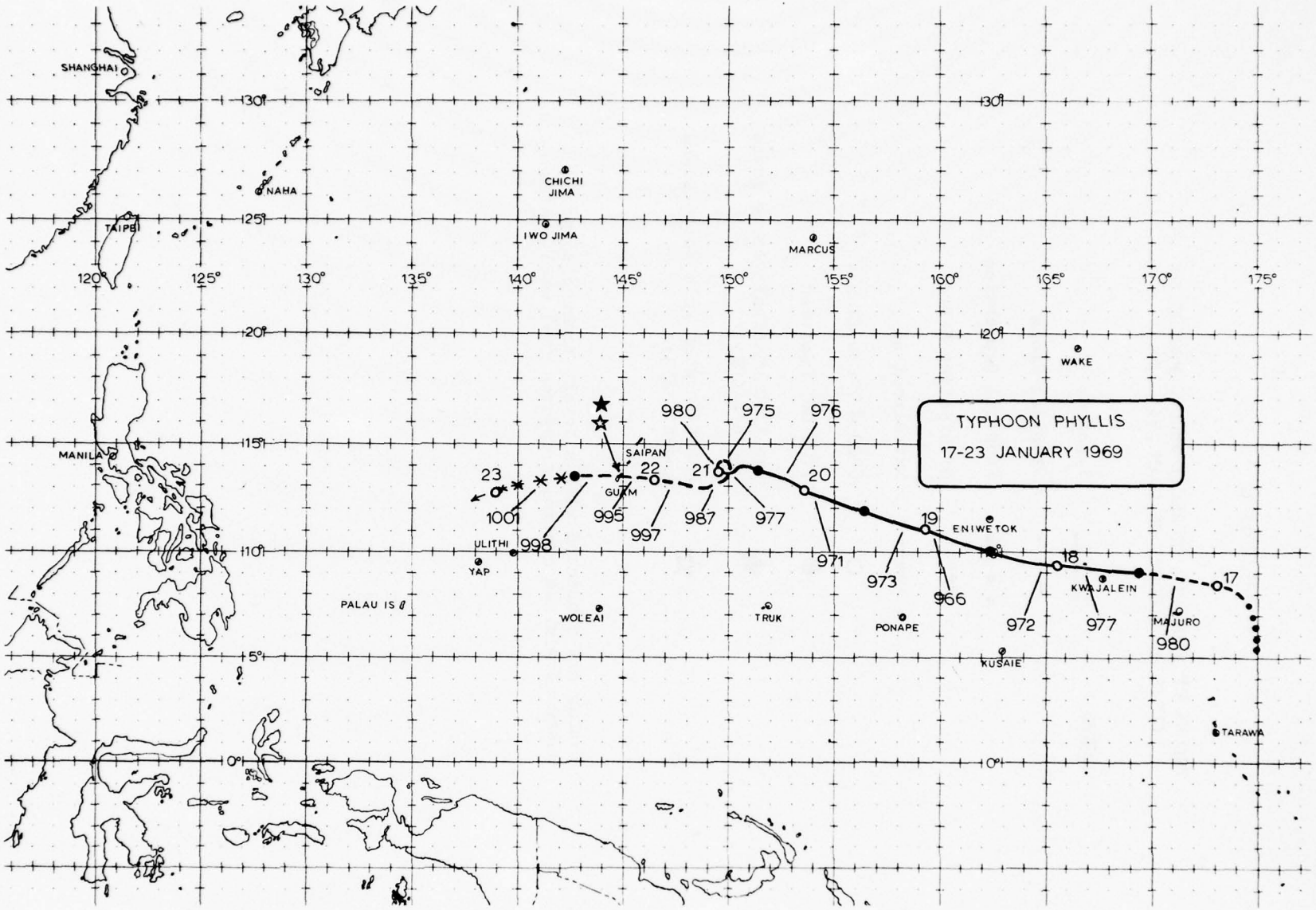
APPENDIX G

TRACKS OF TROPICAL STORMS/TYPHOONS PRODUCING GUSTS ≥ 50 KNOTS ON GUAM 1946-75*

LEGEND

———	Typhoon
- - -	Tropical Storm
• • • •	Tropical Depression
*****	Dissipating Stage
+++++	Extratropical
O	0000 GMT Position
●	1200 GMT Position
★	Position when gale force gusts began (AAFB)
☆	Position when gale force gusts ended (AAFB)

* Tracks are annotated with aircraft reconnaissance observed minimum central pressures (mb) when available.


TYPHOON PHYLLIS
17-23 JANUARY 1969
SHANGHAI
NAHA
TAIPEI
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
MANILA
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
KUSAIE
ENIWETOK
KWAJALEIN
MAJURO
TARAWA
120°
125°
130°
135°
140°
145°
150°
155°
160°
165°
170°
175°
30°
25°
20°
15°
10°
5°
0°
23
22
21
20
19
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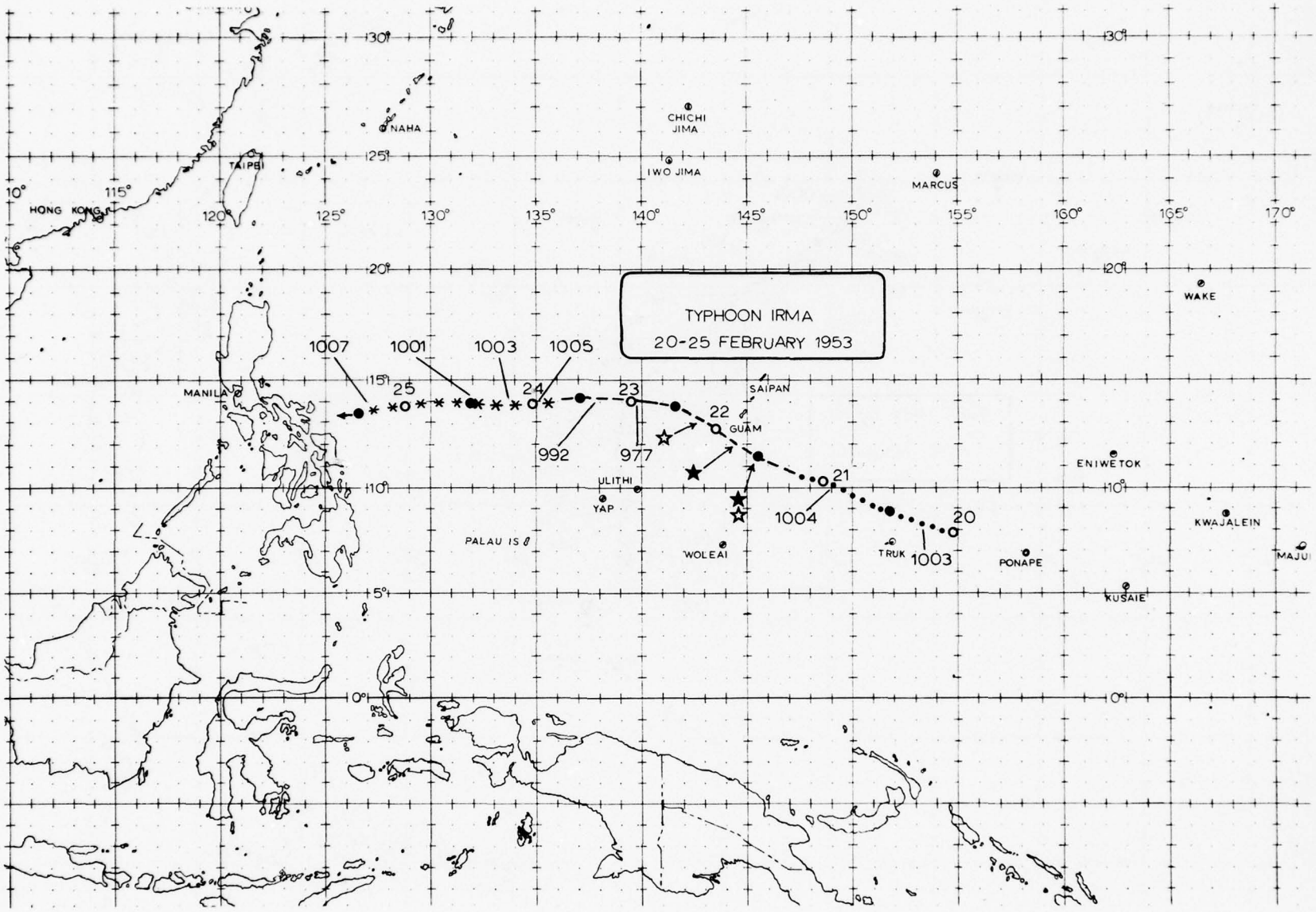
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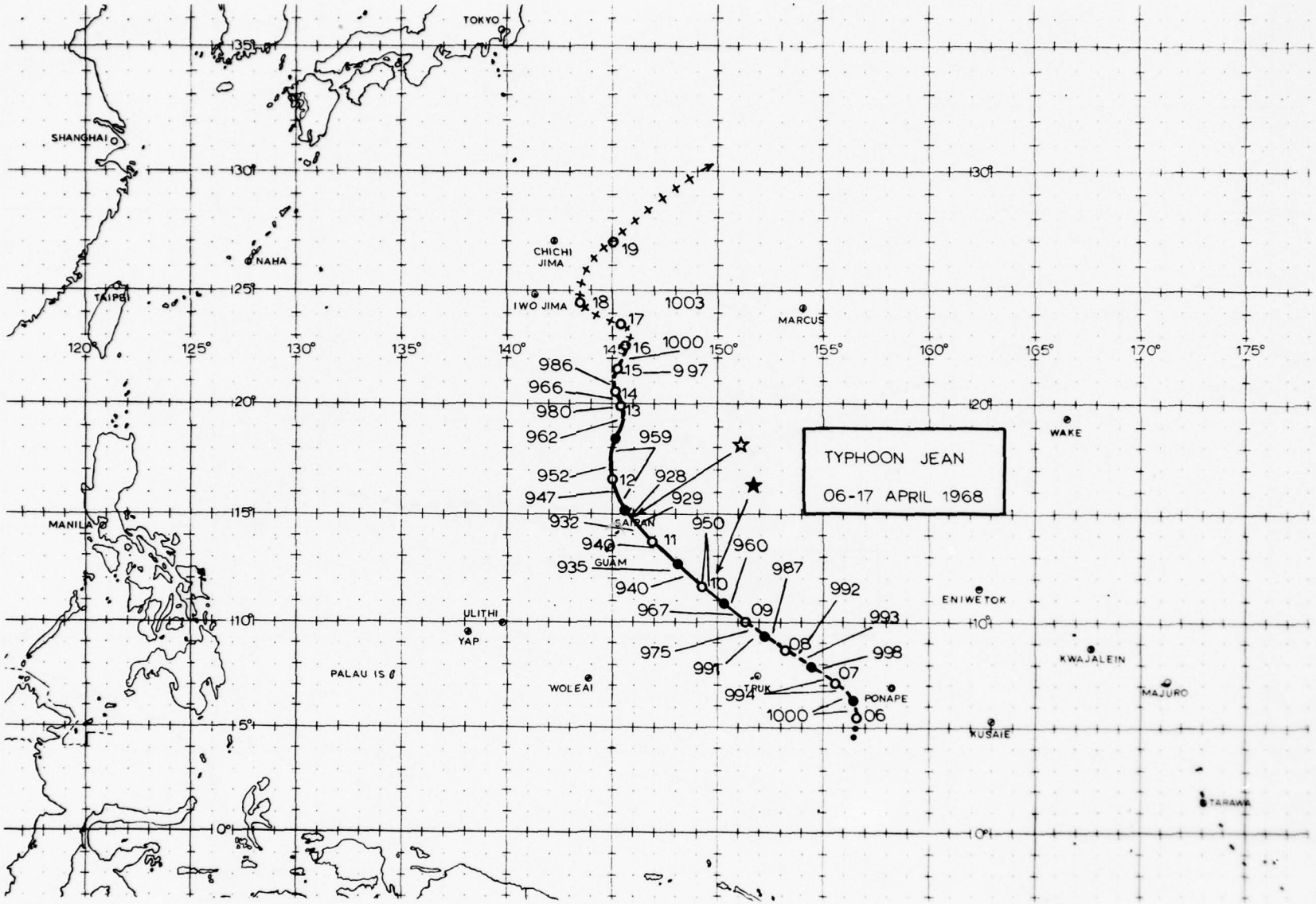
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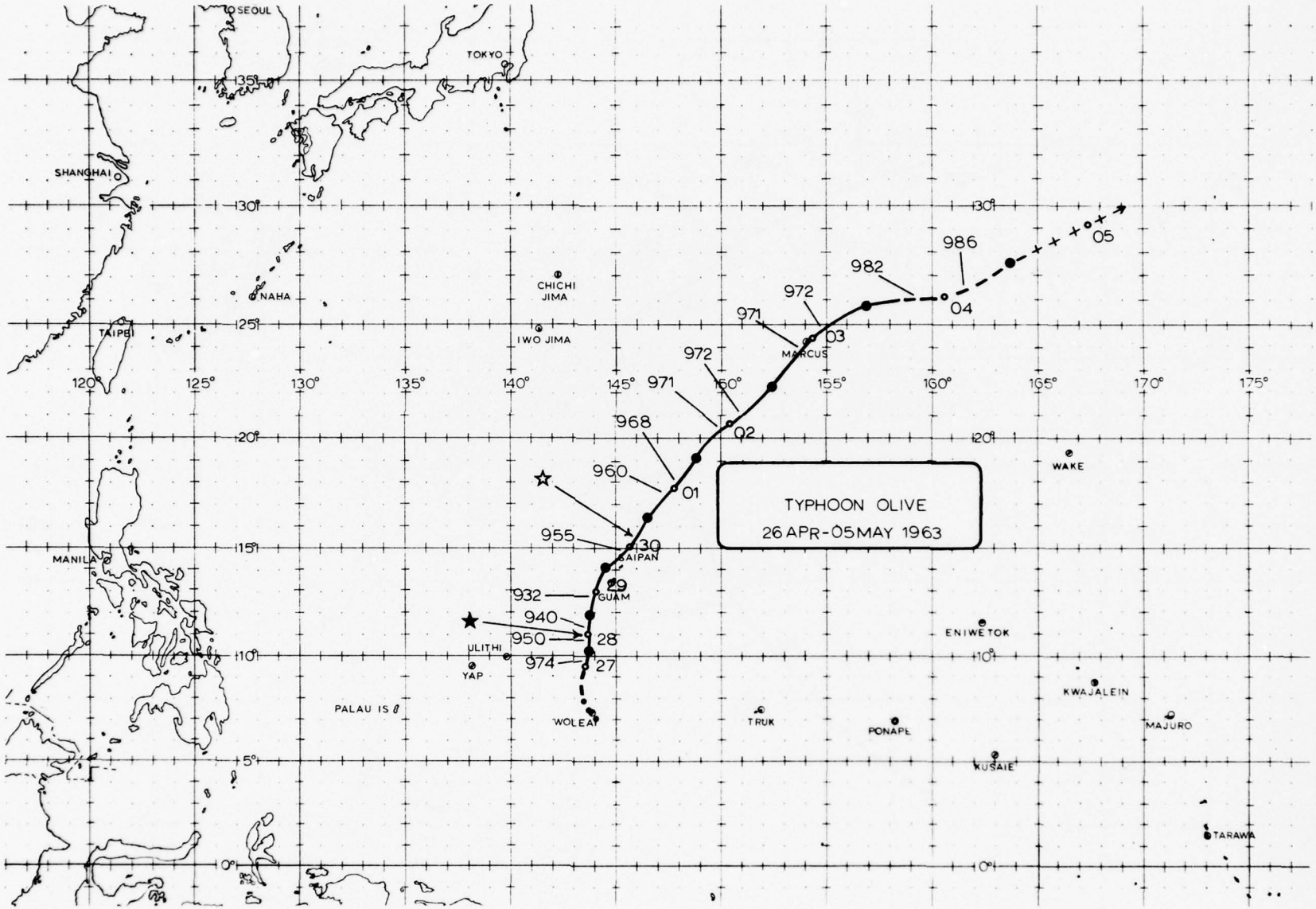
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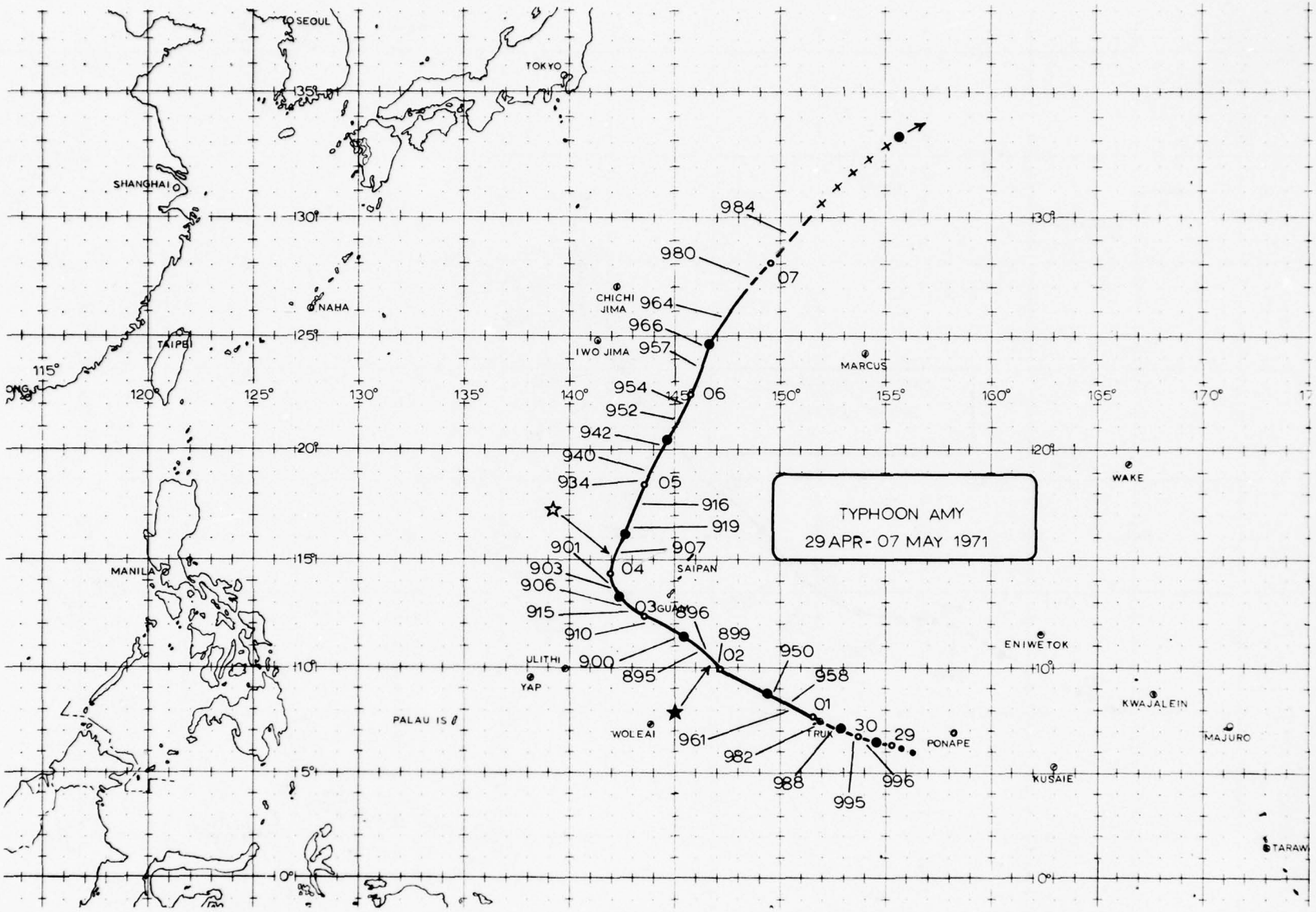
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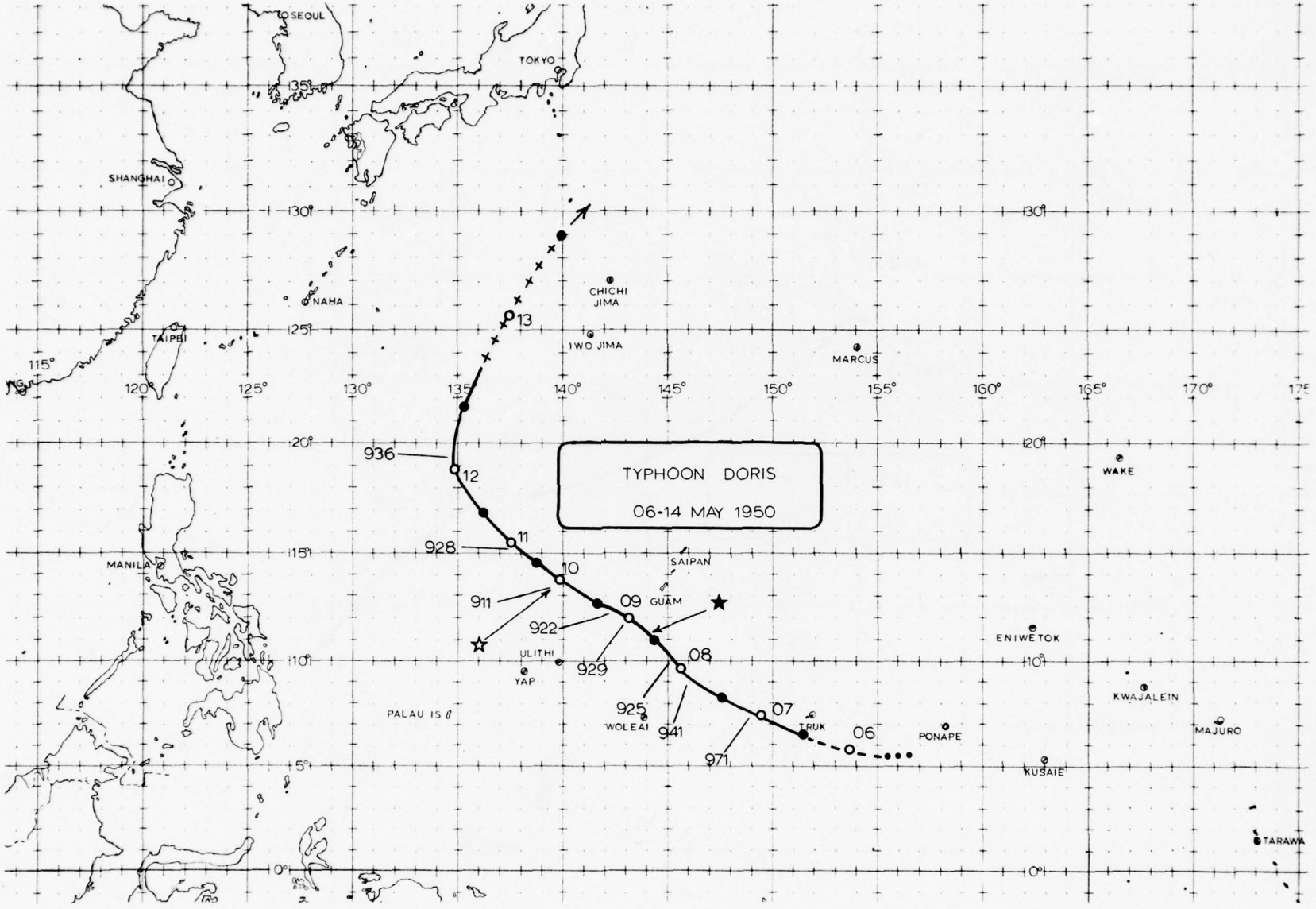
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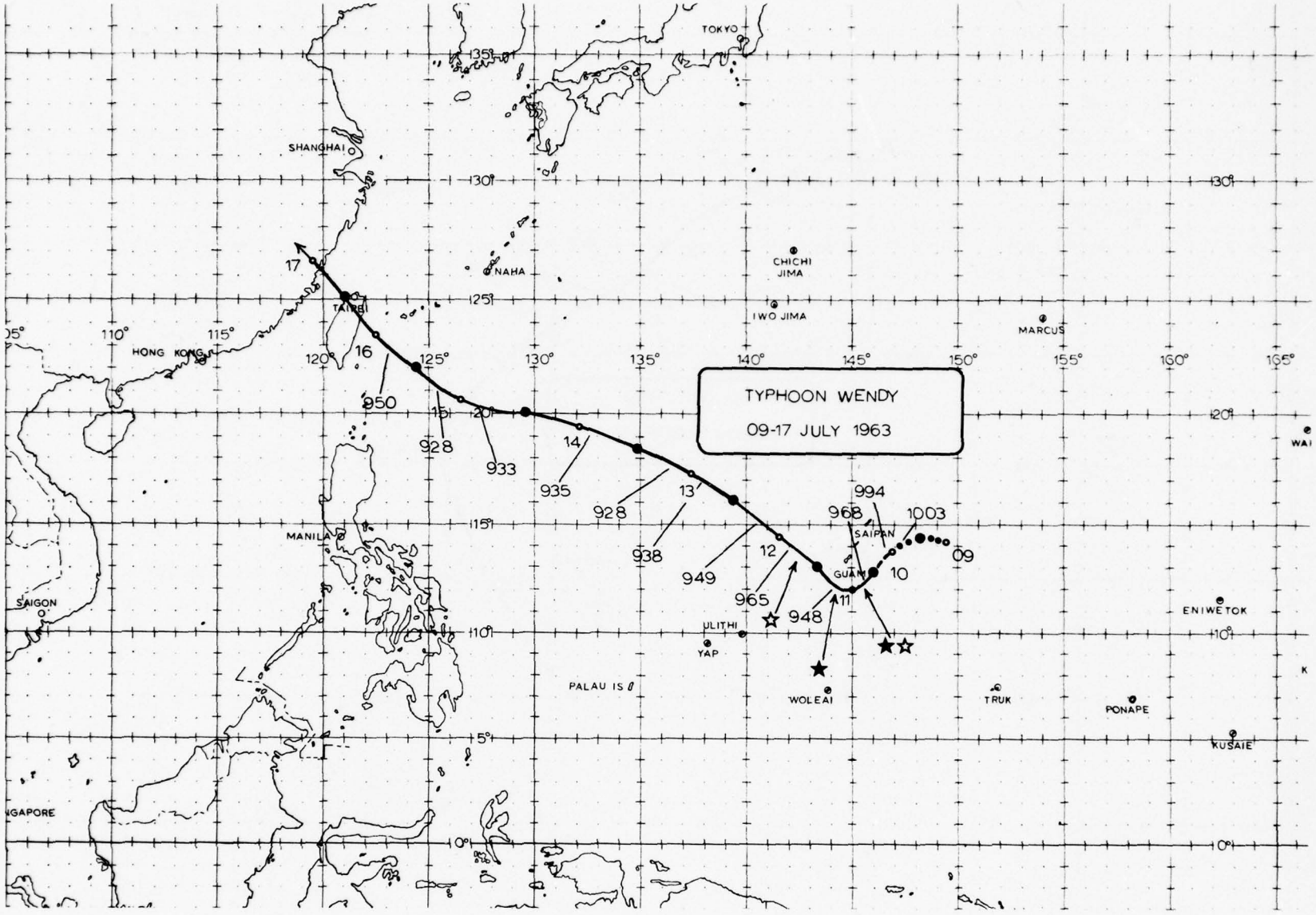
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09-17 JULY 1963
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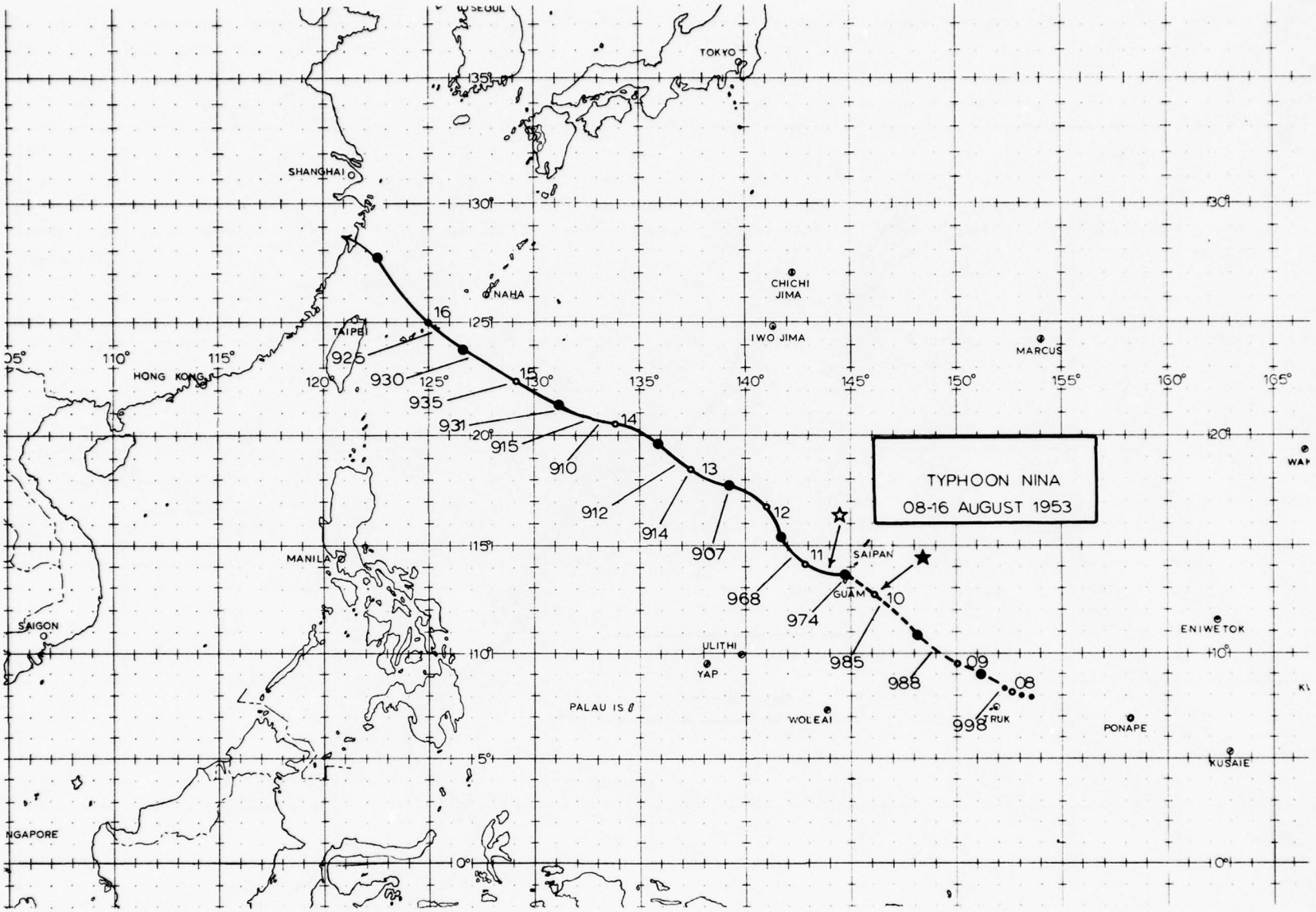
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08-16 AUGUST 1953
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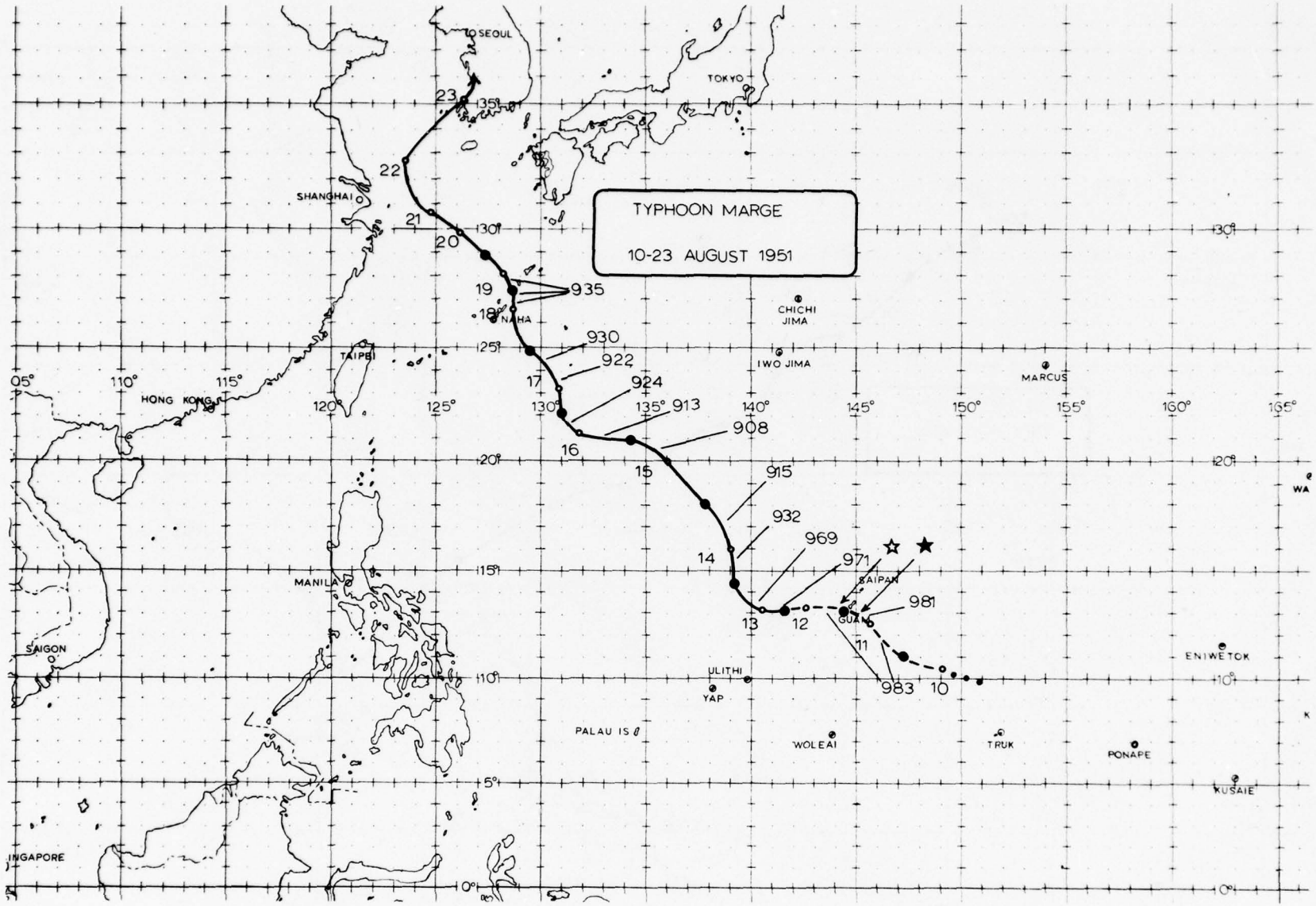
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10-23 AUGUST 1951
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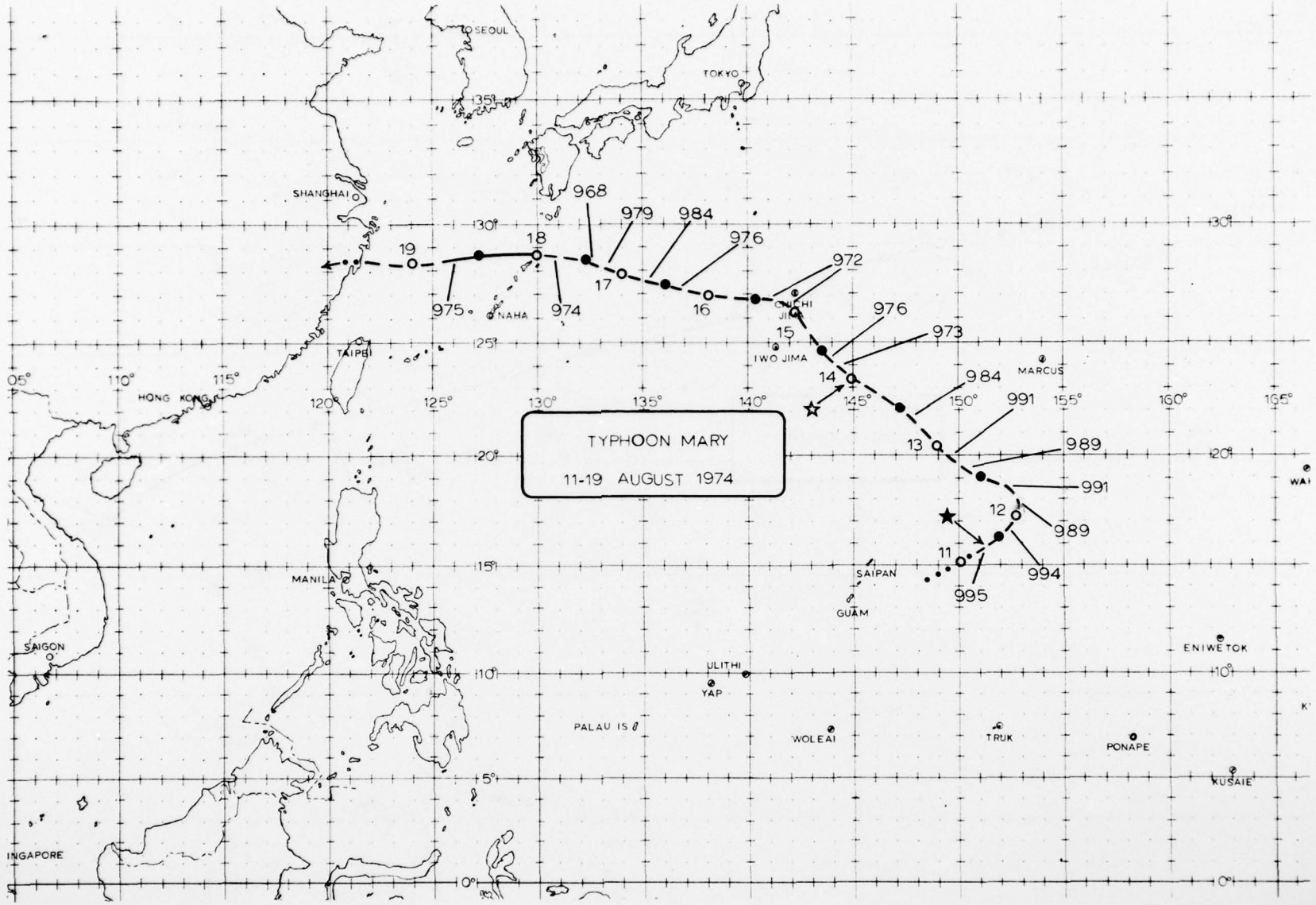
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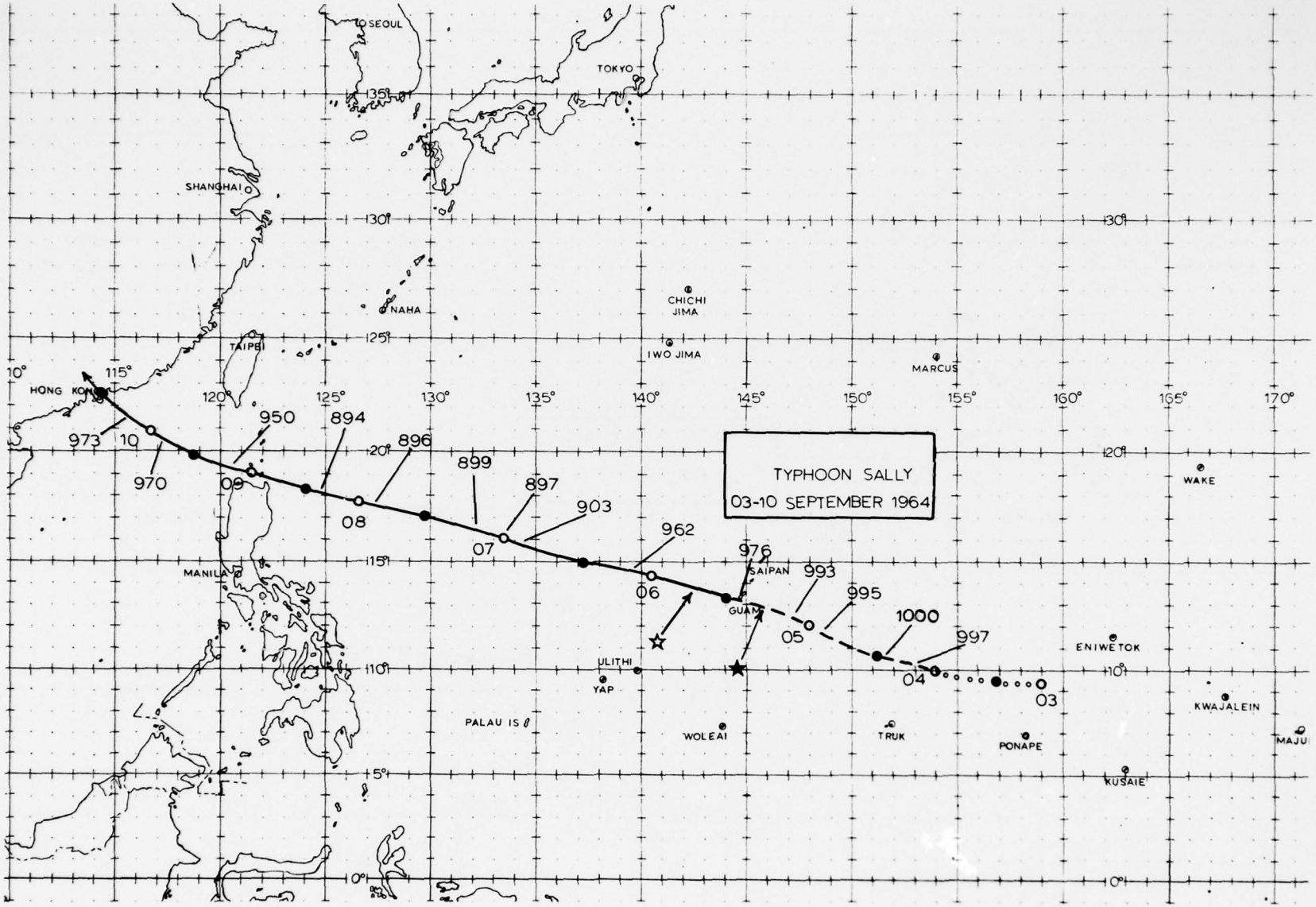
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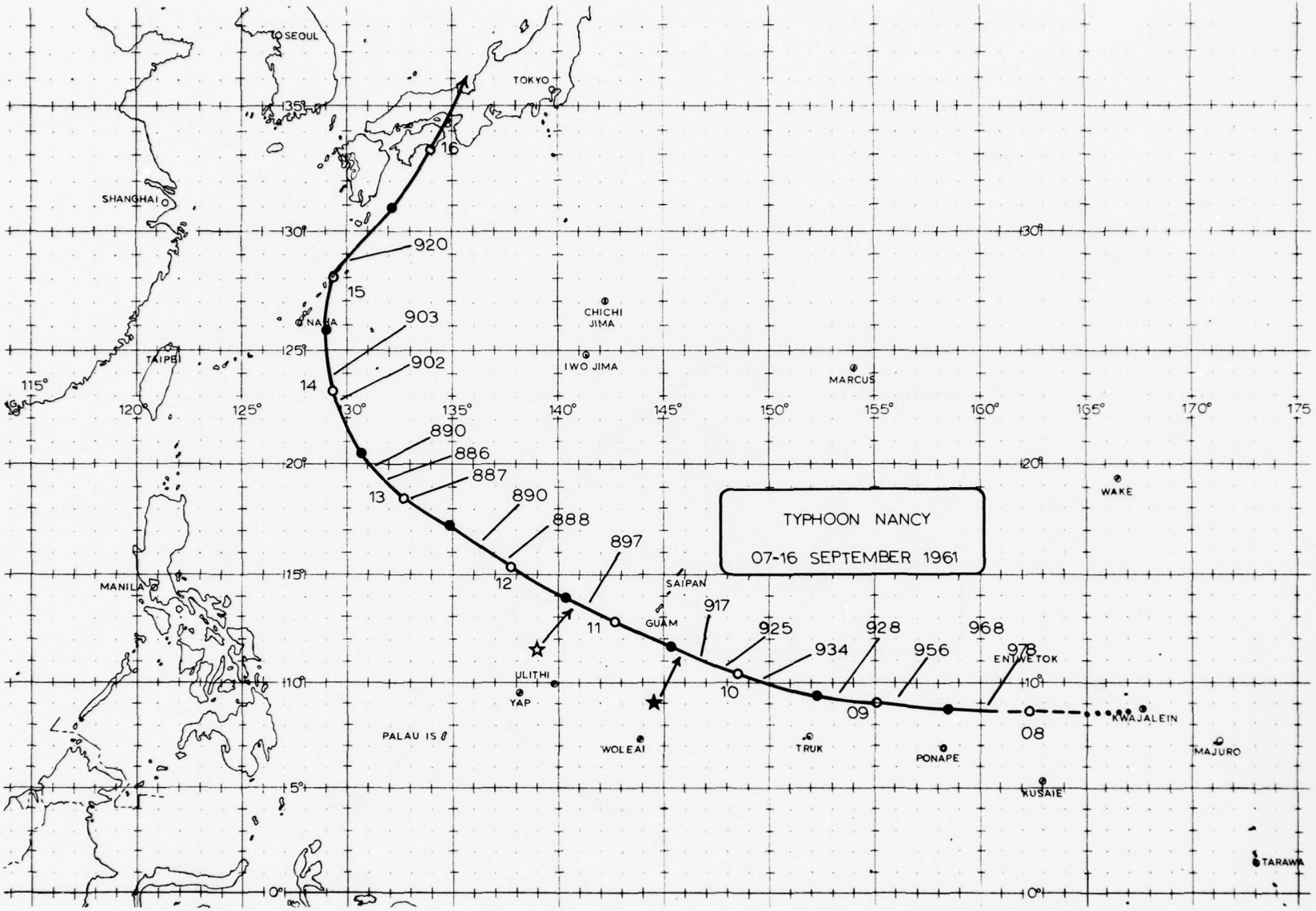
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07-16 SEPTEMBER 1961
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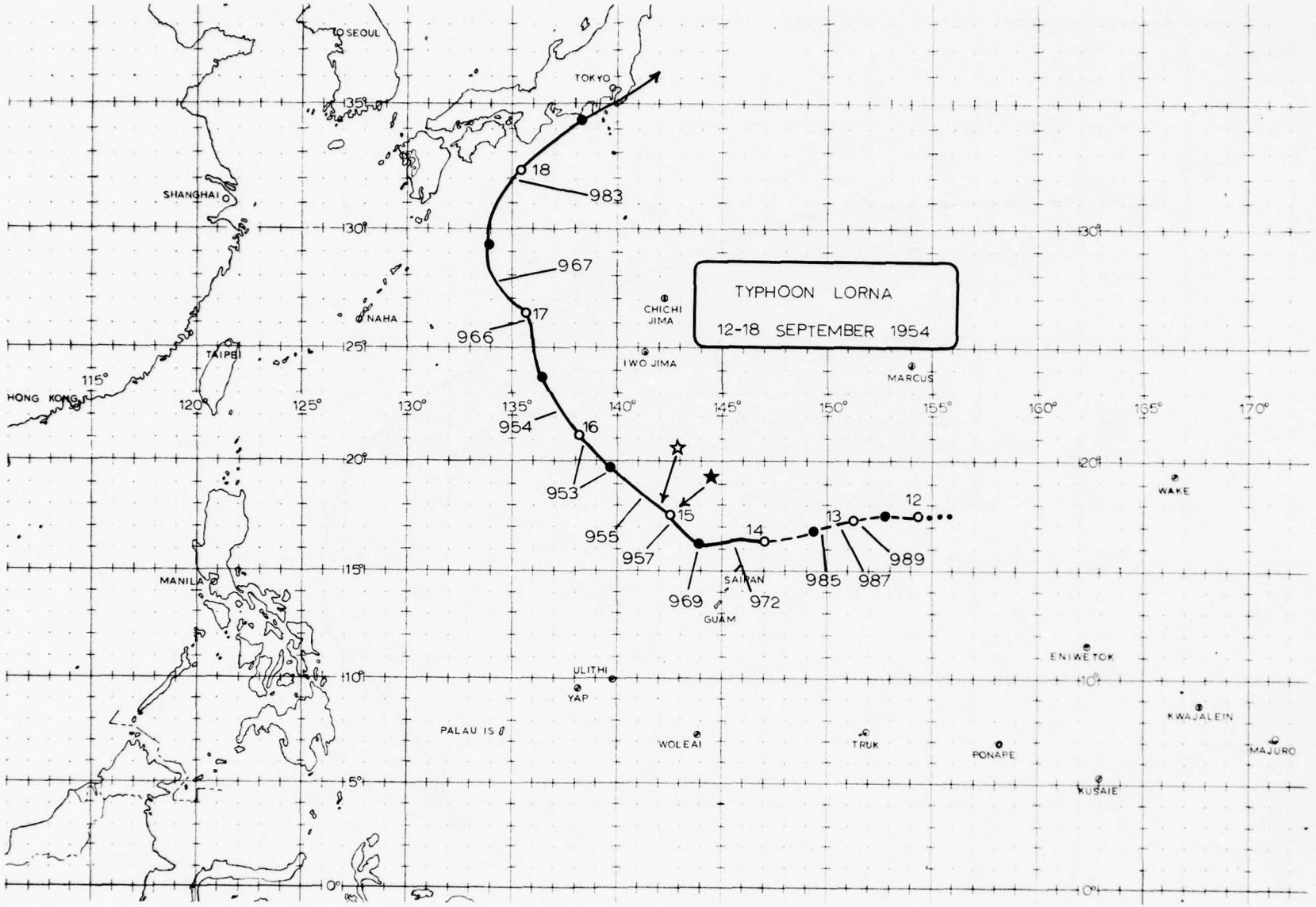
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12-18 SEPTEMBER 1954
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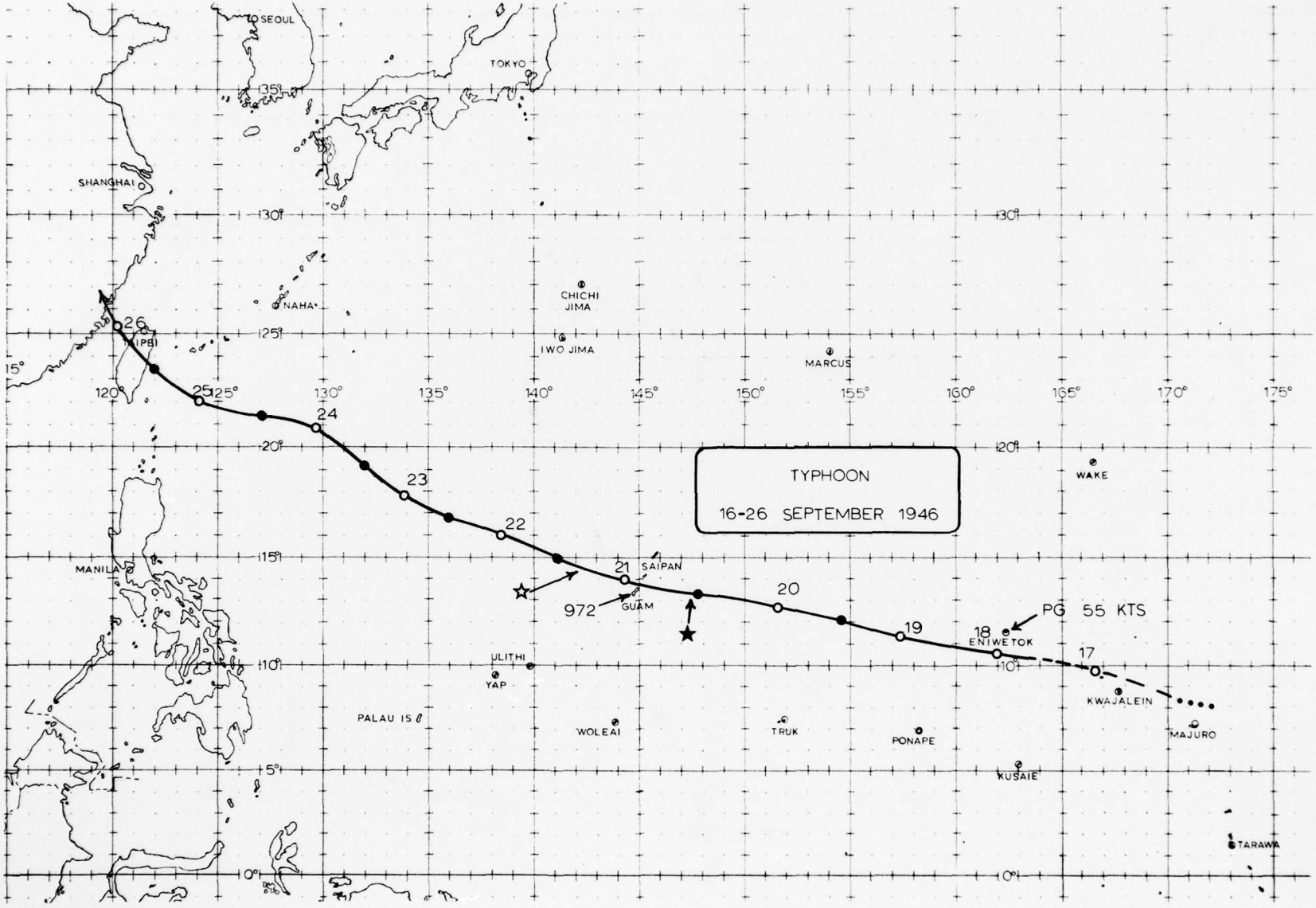
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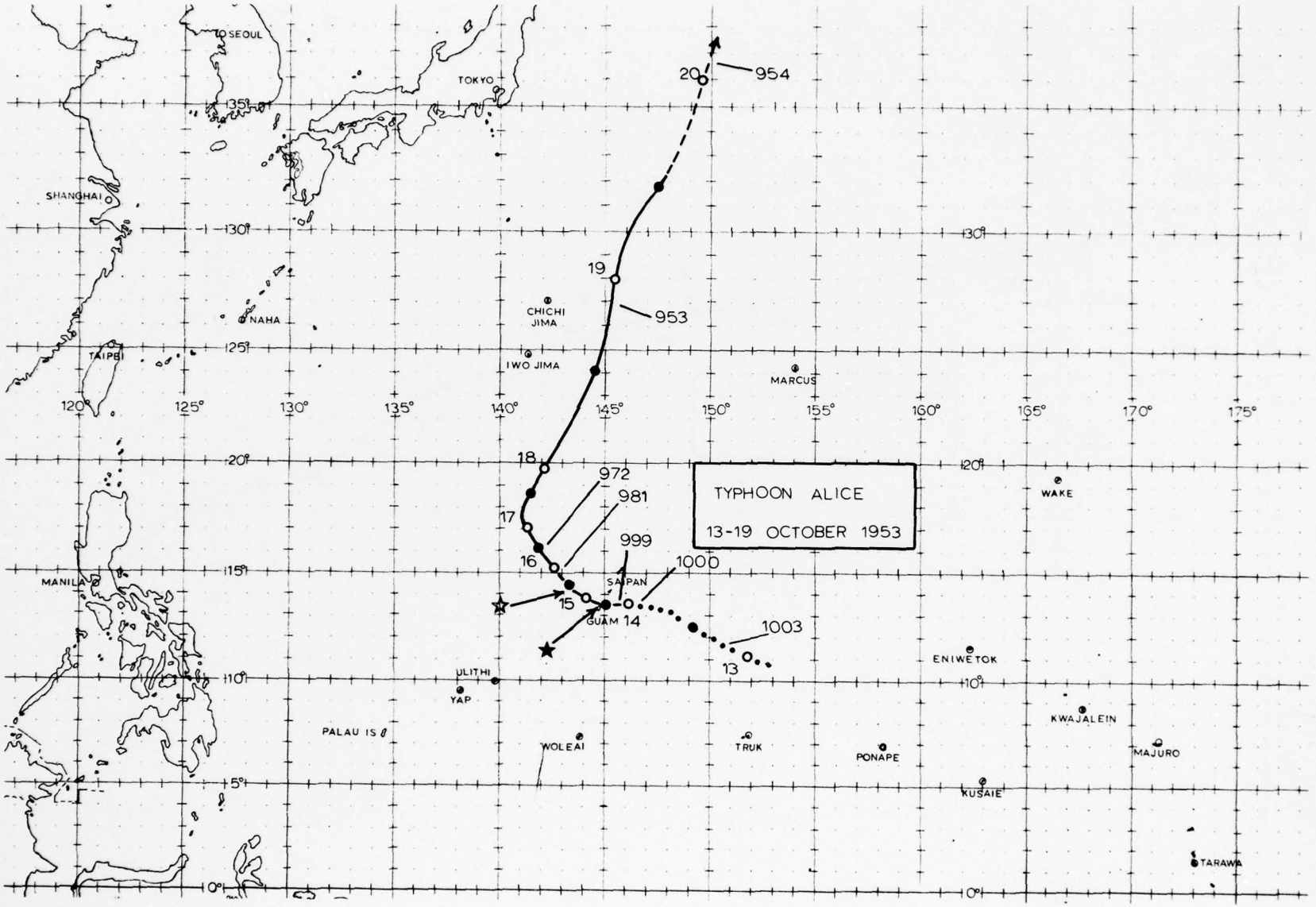
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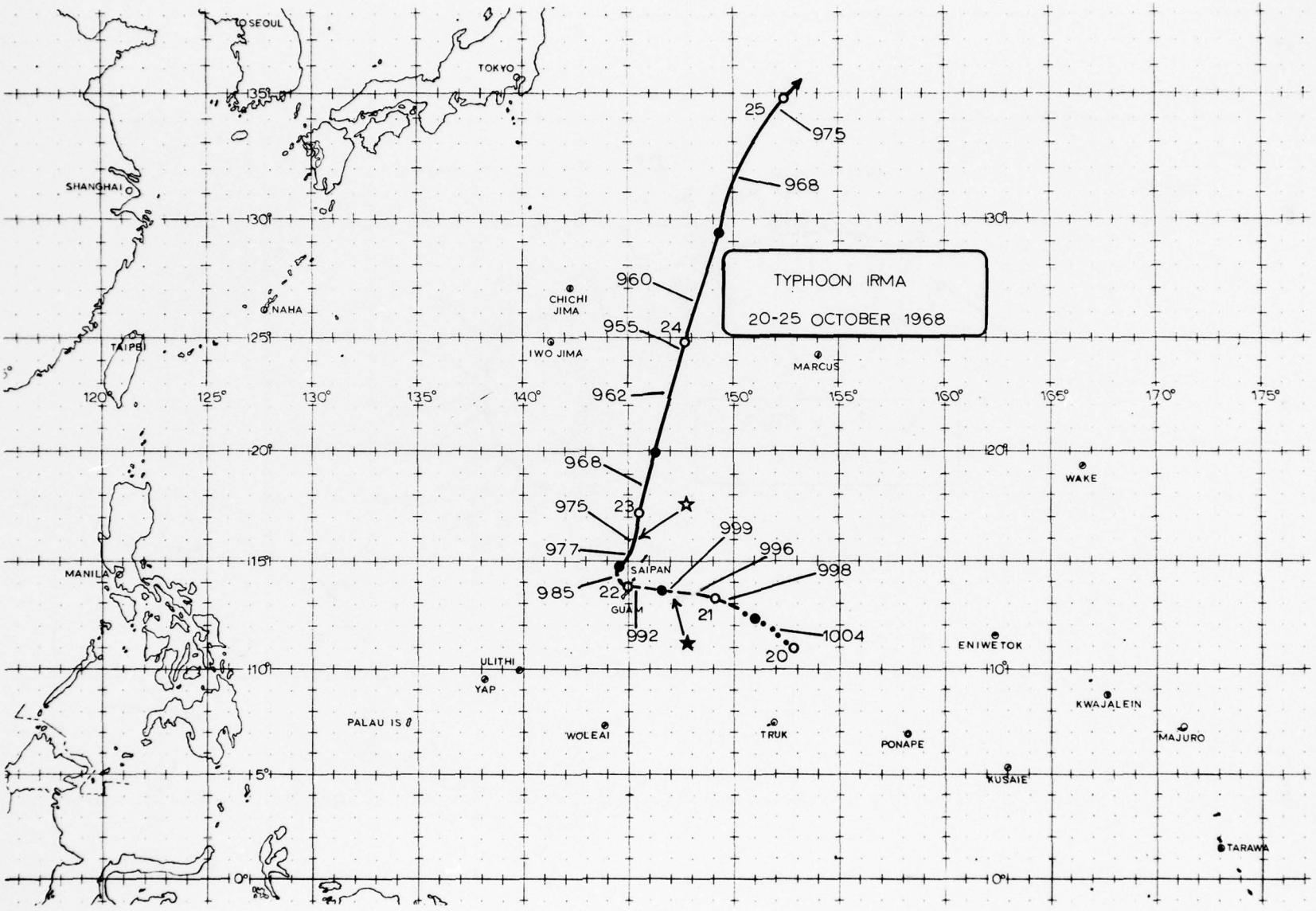
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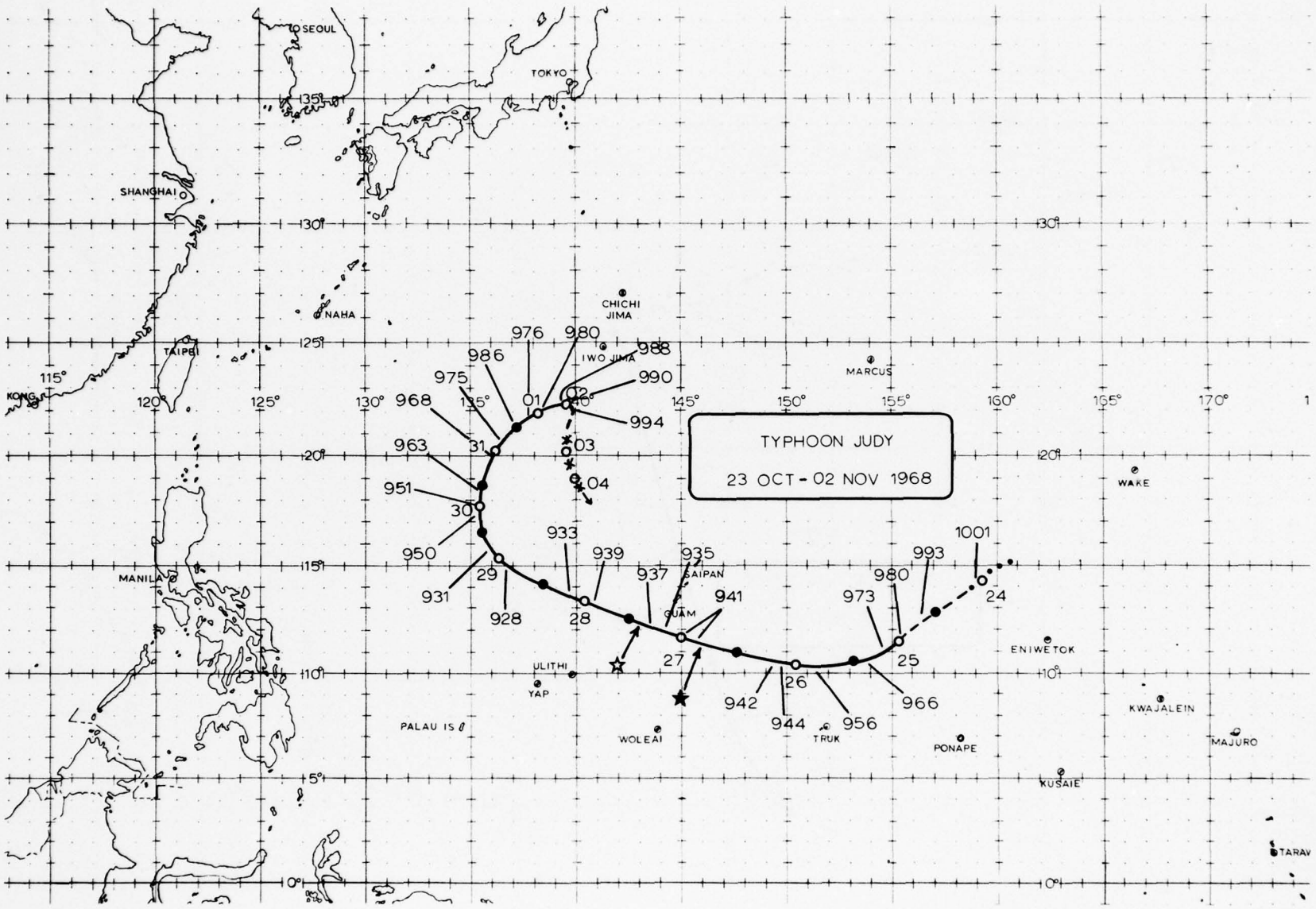
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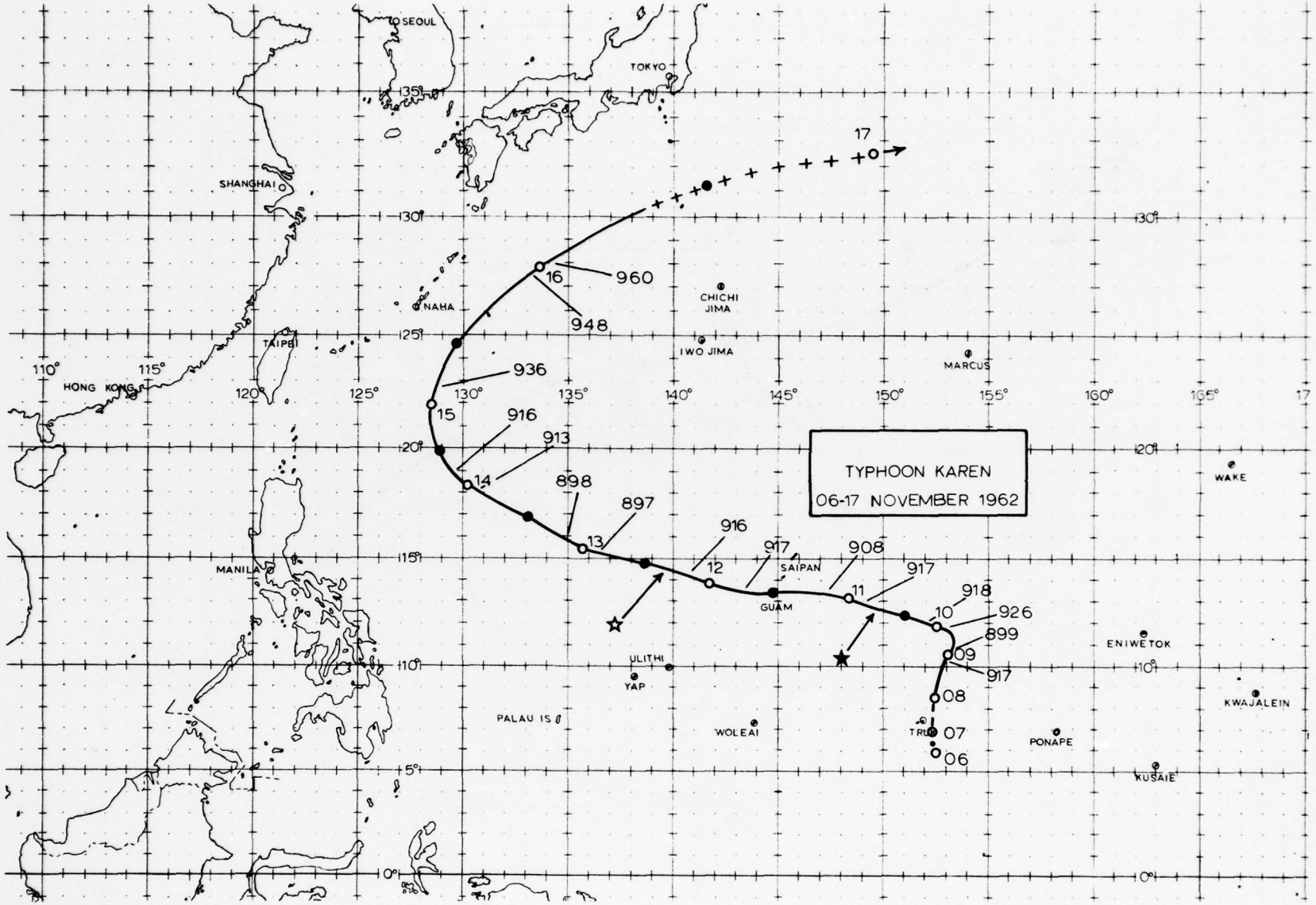
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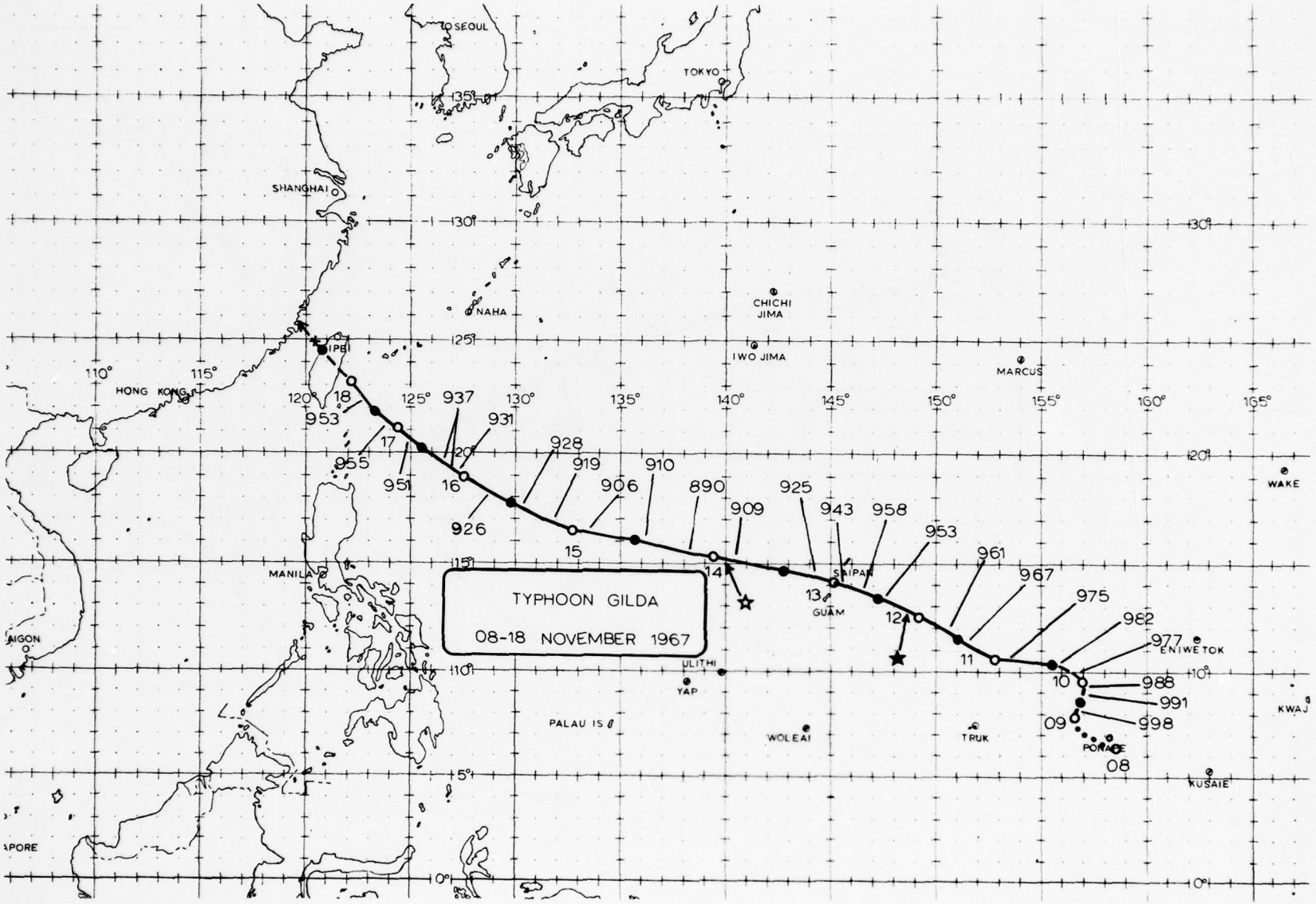
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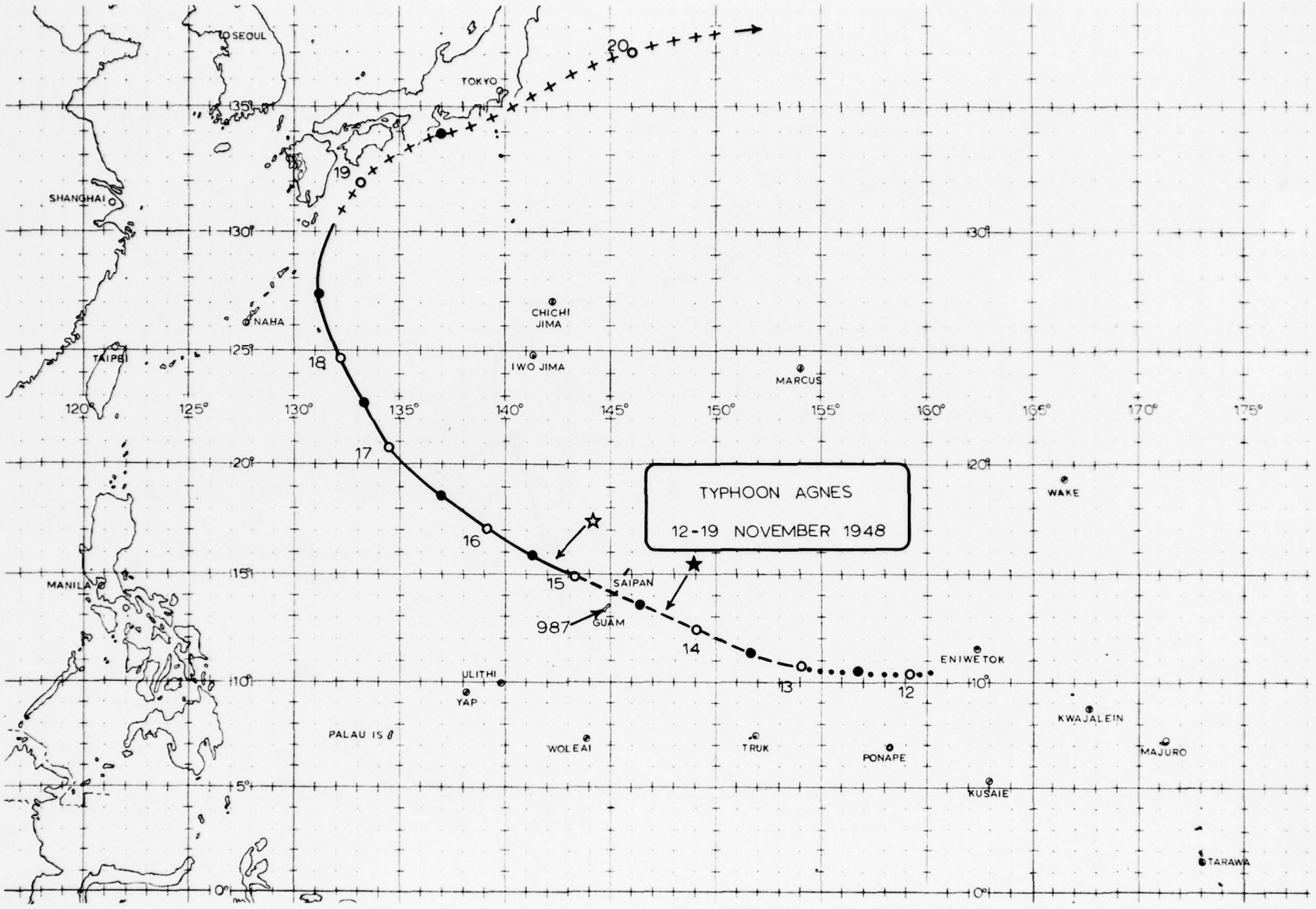
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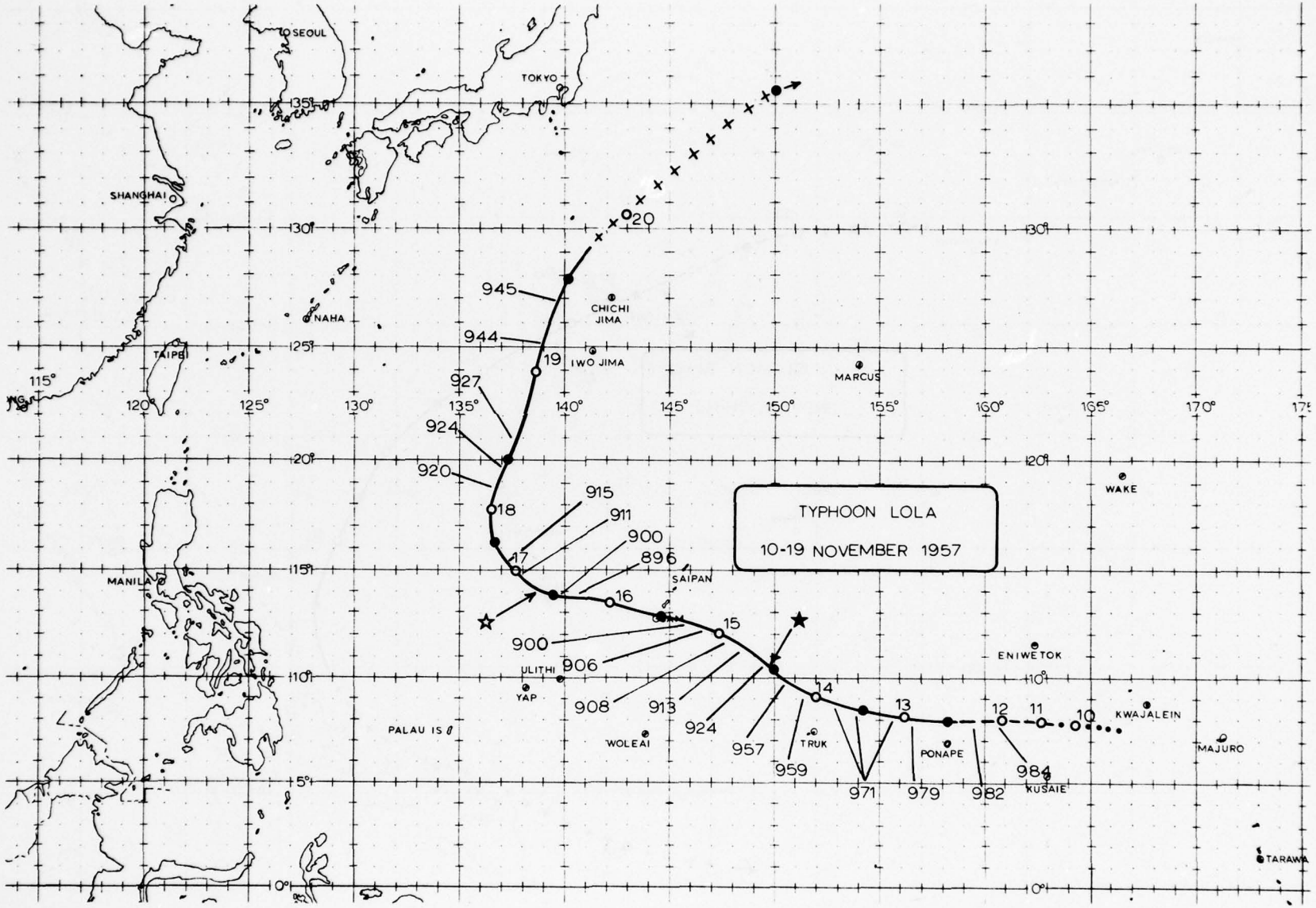
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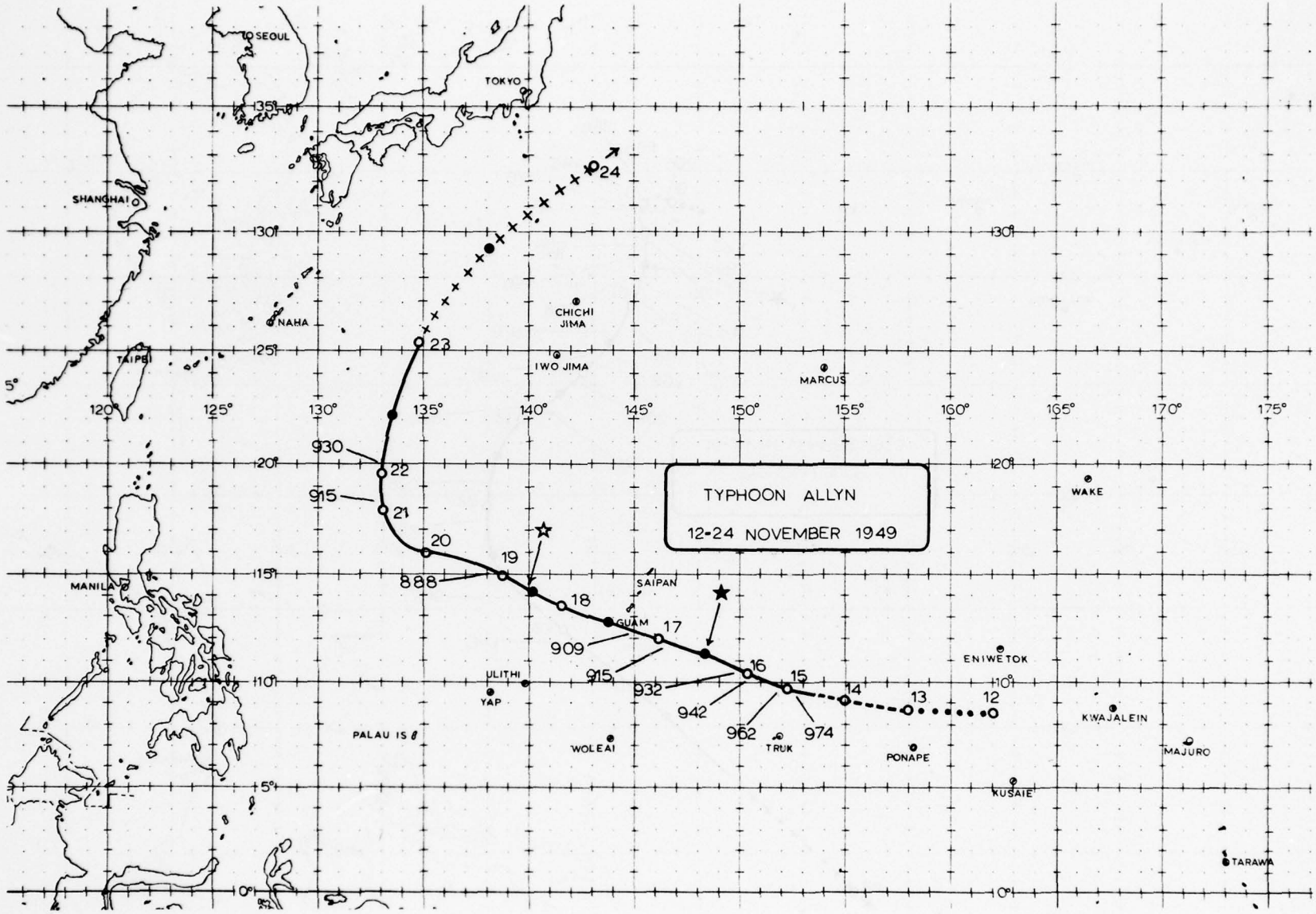
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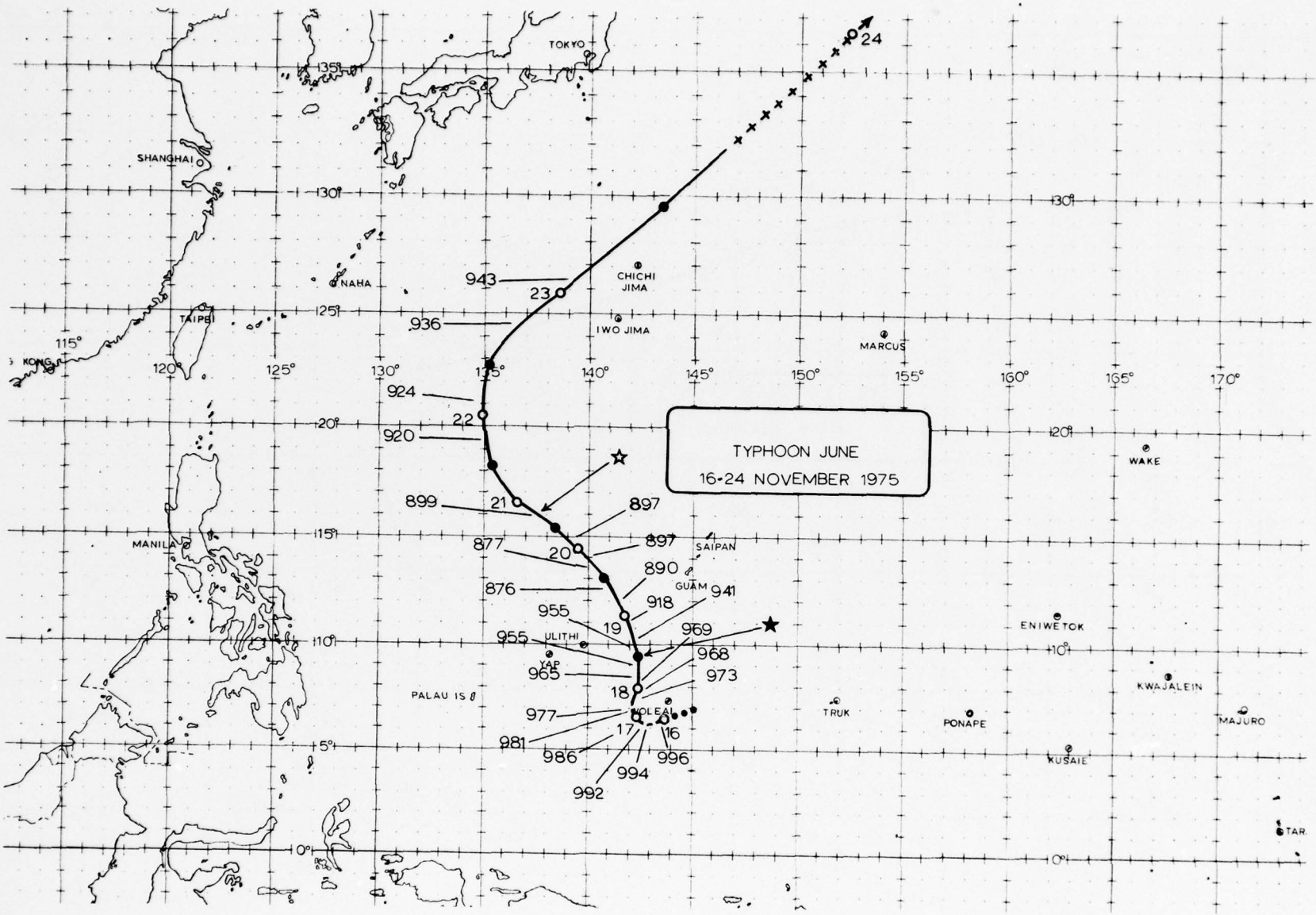
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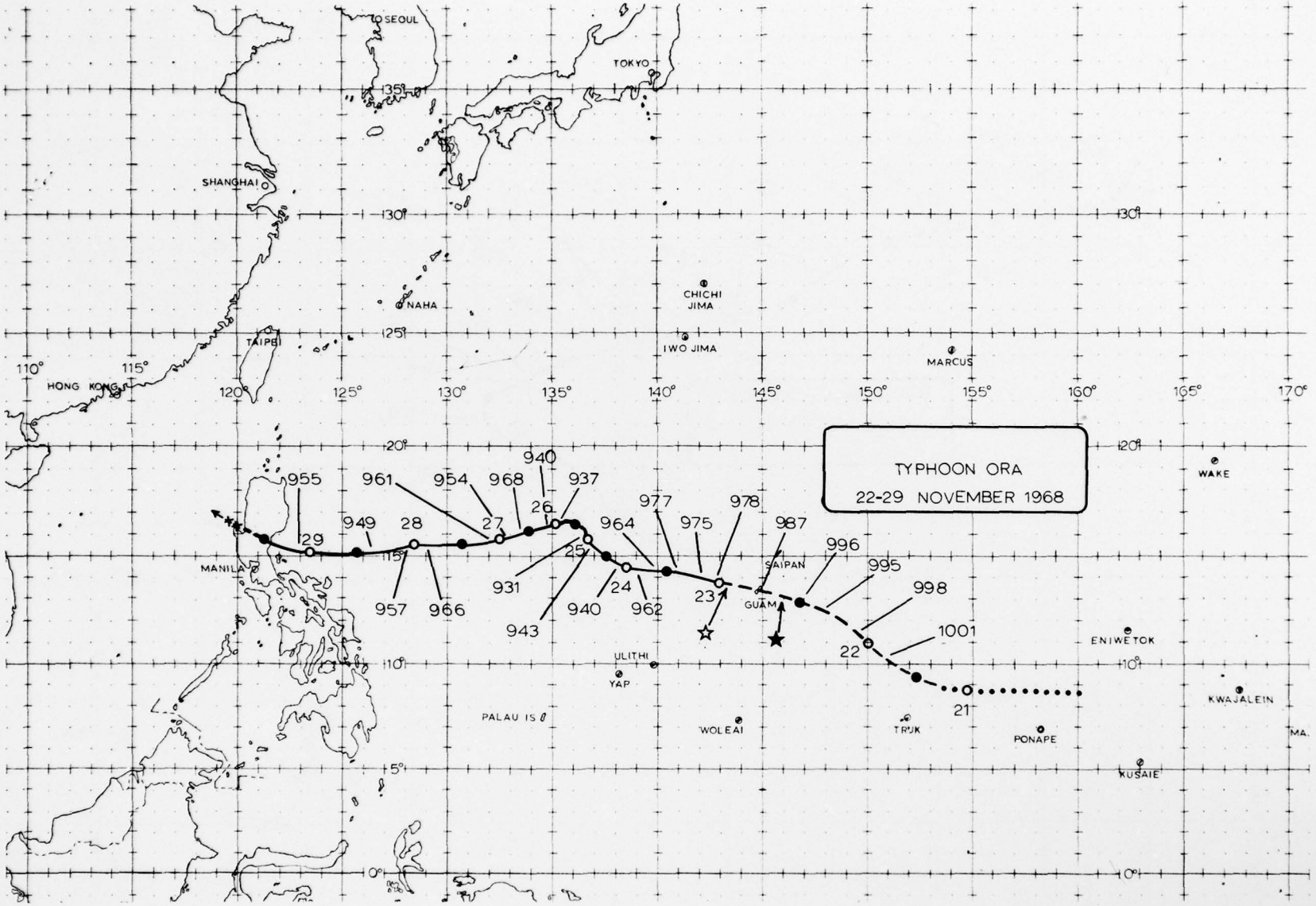
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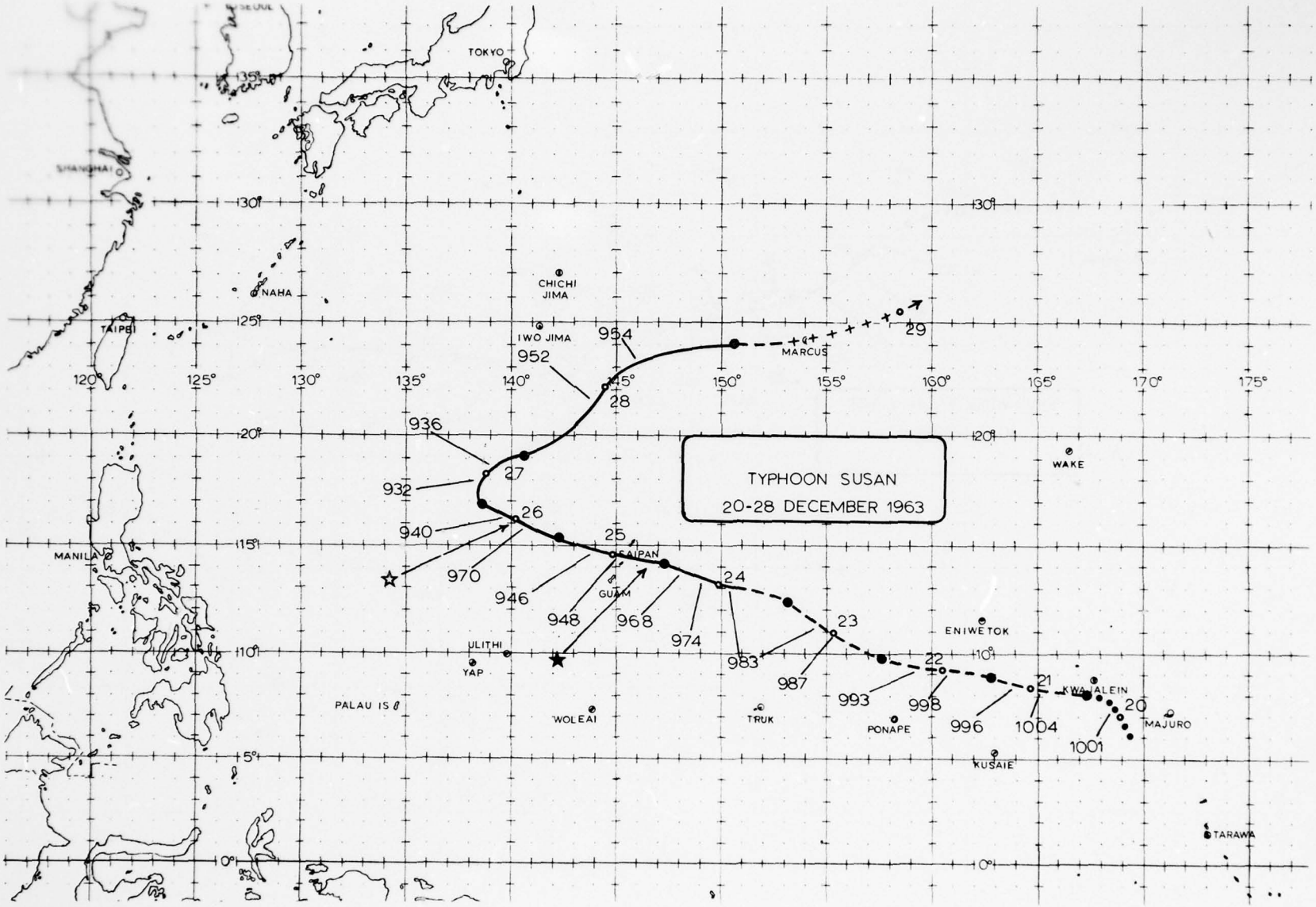
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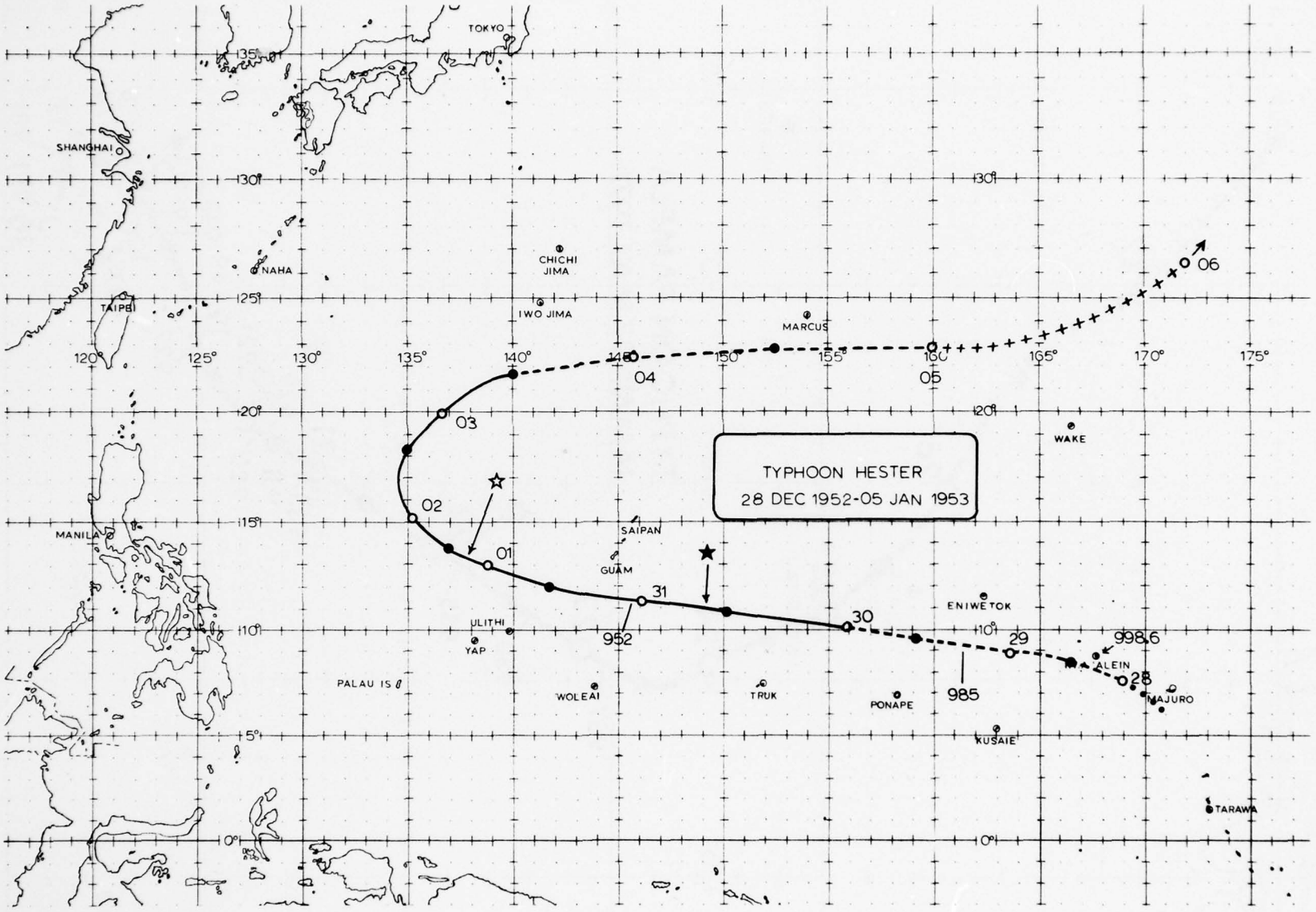
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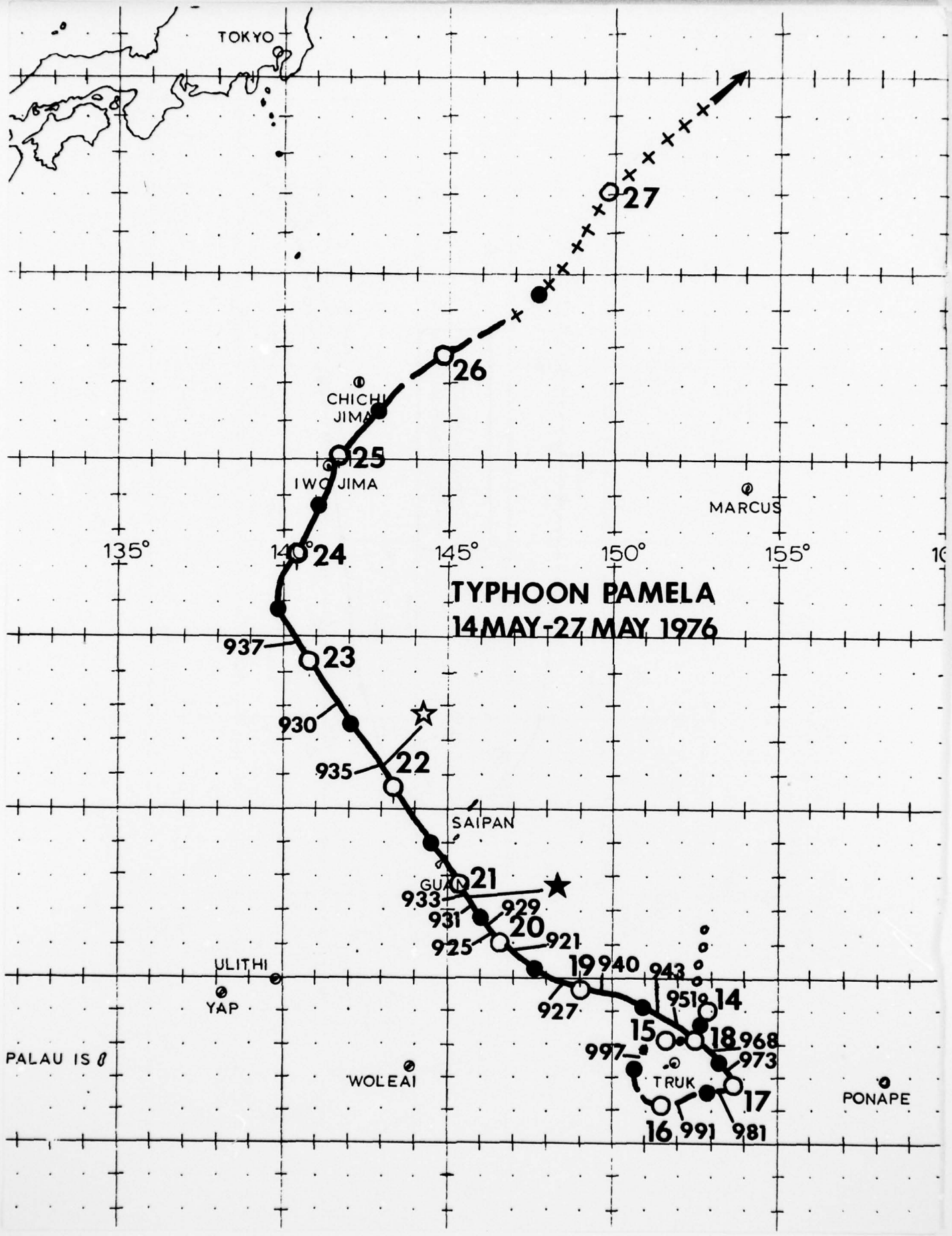
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Tropical cyclones	Climatology
Tropical Storms	Guam
Typhoons	Mariana Islands
Tropical depressions	Micronesia

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A climatology of tropical storms passing within 180 nm of Guam is presented for the period 1948-1975. A review of all typhoons affecting Guam is carried back to 1800 and some noteworthy typhoons of the 1600's are included. The survey encompasses the frequency, behavior, meteorological effects and descriptive chronicles of Guam tropical storms. The major emphasis is on the period since World War II.

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